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OPTIMIZATION OF THE MOOSONEE WATER TREATMENT PLANT FOR CONTROL OF TRIHALOMETHANES

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Optimization of the
Moosonee
Water Treatment Plant for Control of Trihalomethanes

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PIBS 3712E

EXECUTIVE SUMMARY

BACKGROUND

The two main objectives of the study are:

1. Improvement of the water treatment plant performance to meet the Ontario Drinking Water Objectives (ODWO) THMs guideline of 100 µg/L without compromising disinfection. Secondary quality objectives are to achieve a filter effluent turbidity of 0.1 NTU and to reduce aluminum residual to less that 100 µg/L.

2. Sustaining long term performance through skills transfer to plant operating staff and recommendations for plant upgrades where required.

The optimization study was funded by the Ontario Ministry of the Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities should be capable of producing water that meets the new THMs objective and also be capable of improved particle removal without requiring costly upgrades.

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics. Trihalomethanes are suspected of increasing the risk of cancer following long term exposure. The Ontario government has lowered the guideline from a maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

The associated treatment parameter of turbidity was also subject of the optimization effort. The ODWO for turbidity is 1 NTU, but current research indicates that a filter effluent turbidity of 0.1 NTU is desirable to provide protection from cryptosporidium. To reduce potential for disease outbreaks, this study will evaluate the feasibility of obtaining a turbidity of 0.1 NTU in the filter effluent.

The optimization of a water treatment plant consists of evaluating the existing treatment units, conducting laboratory testing to determine the best choice and dosage of the treatment chemicals and making changes to plant operation.

EXISTING CONDITIONS

The original water treatment plant was built in 1964 and expanded in 1984. The plant is owned by the Moosonee Development Area Board, and is presently operated by the Ontario Clean Water Agency (OCWA). The plant services a population of approximately 2,000. The raw water characteristics are:

Colour: 40 to 300 TCU
Turbidity: 2 to 30 NTU
pH: 7.1 to 8.0
Alkalinity: 25 to 312 mg/L

Plant flows are generally:	Average day	935 m^3/d (650 L/min)
	Maximum daily flow	1,080 m^3/d (750 L/min)

The water treatment plant consists of:

- ⇒ Low lift pumping station drawing raw water from Store Creek.
- ⇒ Raw water supply main to the treatment plant.
- ⇒ Coagulant feed systems for alum or acidified alum, caustic soda and polymer.
- ⇒ Two (2) Graver Reactivators/clarifiers.
- ⇒ Four (4) contact tanks.
- ⇒ Four (4) dual media filters.
- ⇒ One (1) clearwell storage located under the filter area.
- ⇒ Chlorine and caustic soda injection at the filter effluent.
- ⇒ Three (3) vertical turbine high lift pumps.

PERFORMANCE ASSESSMENT

After a site visit performed in May 1996, conclusions related to the current plant operation were made and are summarized as follows:

- The plant is in operation 24 hours per day all year round and is near or sometimes over its capacity. The plant reaches its maximum capacity during February and March from the bleeding that is done by residents to keep piping from freezing. Operating pressure in the distribution system is maintained at a maximum of 275 kPa (40 psi) to reduce water consumption.
- The rise rate in the two clarifers are within the MOE guideline. However, the MOE recommends lower rates under the conditions of cold highly coloured water as occurs in Moosonee. These units are not performing well since it is very difficult to maintain a sludge blanket in the clarifiers due to the small floc formation often typical of high coloured water with relatively low turbidity. The clarifiers are therefore operated as sedimentation tanks most of the time. A longer residence time and lower rise rate would be required to settle the floc. Floc carry over onto the filters is frequently observed reducing the filtration time between backwashes. The Reactivators are currently operated at their maximum practical capacity and are a limiting factor in the treatment capacity of the plant.

The parameters exceeding the Ontario Drinking Water Objectives (ODWO) from water sampling programs performed in the summers of 1996 and 1997 are summarized as follows:

- The THMs measured in the distribution system in 1996 varied from 13 to 320 µg/L, for an average of 130 µg/L. THMs were in excess of the new guideline in July and August, but may not be over the annual quarterly average. The level of THMs is normally higher during the summer due to higher water temperature. Sampling performed by the MOE for the Drinking Water Surveillance Program (DWSP) showed lower levels of THMs in compliance with 100 µg/L for the fall, winter and spring.

- The THMs measured in the distribution system during the summer of 1997 varied from 67 to 130 µg/L, for an average of 80 µg/L. The level of THMs was improved in the summer of 1997 by maintaining an average pH in the treated water of 7.2, by comparison to a pH of 8.1 for the summer 1996. However, potential corrosion problems may occur over time in the distribution system by maintaining a lower pH.
- The average treated water turbidity was quite variable and ranged from 0.2 to 2.5 NTU. The objective of this study is for a filter effluent turbidity of 0.1 NTU to reduce potential for cryptosporidium outbreaks.
- The treated water colour was variable and ranged from 1 to 7 TCU, frequently exceeding the ODWO of 5 TCU. While colour is not a health-related parameter, it can be an indication of precursors that will form THMs.
- The aluminum level in the raw water varied from 98 to 599 µg/L, and the residual aluminum in the treated water ranged from 83 to 1,210 µg/L, for an average of 328 µg/L which is much higher than the ODWO of 100 µg/L. The guideline for aluminum residual is an operational guideline and was set to reduce post-precipitation in the distribution system.

OFF-SITE BENCH SCALE EVALUATIONS

Measurement of supernatant turbidities and colour in the MOE lab on jar tests performed on Moosonee raw water showed that PACL was much better at removing turbidity and colour than alum. The performance of alum though was acceptable. Floc quality was similar for both treatments. Results showed that aluminum residuals were above the ODWO of 100 µg/L for the alum treatment, but below the ODWO for PACL. The optimum PACL dosage was 120 mg/L together with Percol LT24. The optimum alum dosage was 180 mg/L together with 8170 polymer.

For the alum treatment the level of THMs was 16 µg/L, and for the PACL treatment the THMs level was 30 µg/L. The higher THMs with PACL was surprising given that the TOC level in PACL-treated water was slightly lower than in the alum-treated water. The pH in both samples was nearly the same just prior to chlorine addition.

In general, excellent results were achieved with PACL and LT24 Polymer. PACL was significantly better than alum in producing lower turbidities and lower aluminum residuals in the supernatant. THMs were acceptable but higher than with alum. PACL is also expected to perform better in cold water and consumes less alkalinity. It is anticipated that a pre-alkalinity feed may not be required however acidification would still need to be practiced during periods of high alkalinity and pH.

FULL SCALE TESTING

Full scale testing using polyaluminum chloride (PACL) and LT20 polymer was performed at the Moosonee South Water Treatment Plant in February 1997 to evaluate if PACL is better than alum at removing colour, turbidity and THMs precursors under real operating conditions.

The level of THMs measured in the treated water at the plant when dosing PACL varied from 53 to 97 µg/L, and the level of THMs when dosing alum varied from 75 to 82 µg/L. The results indicate that both coagulants are comparable in terms of THMs formation. The level of THMs remained under 100 µg/L for both coagulants which is normally expected for that time of the year.

The results indicate an improvement in the turbidity level of the treated water with turbidity ranging from 0.1 to 0.15 NTU when dosing 68 mg/L of PACL and 0.8 mg/L of LT20. The turbidity of the raw water for the two days ranged from 2.7 to 3.0 NTU.

The colour in the treated water when dosing alum was 3 TCU. It appears that the treated water colour improved slightly with PACL with results ranging from 1 to 2 TCU, but there is not sufficient data to conclude that this reduction with PACL represents a real trend.

Maxxam Analytics analyzed all samples for aluminum residual except for the sample on February 7 which was analyzed on-site by the MOE. The analytical method used by Maxxam Analytics is the ICP method (Inductively Coupled Plasma Atomic Emission Spectroscopy). Aluminum was tested on-site with a DR 2000 using the ECR method (Erichrome Cyanine Reagent). The results for February 6 when dosing PACL show a level of aluminum residual in the treated water of 91 µg/L which is below the ODWO of 100 µg/L. The results measured on February 7 with PACL show a lower level of aluminum residual, at 19 µg/L. The different analytical method used may explain the lower level measured on February 7. The aluminum residual level measured when dosing alum from February 17 to 19 varied from 94 to 116 µg/L. The limited amount of data available when dosing PACL makes it difficult to conclude if PACL effectively reduced the level of aluminum residual in the treated water.

The results of the full scale plant testing indicate that there is no real benefits regarding colour, aluminum residual and THMs formation to switch to PACL. Therefore, it was recommended to continue using alum as primary coagulant.

RECOMMENDATIONS FOR PLANT SCALE MODIFICATIONS

The following is a summary of recommendations for plant and operational modifications required to ensure that the Moosonee South Water Treatment Plant will comply with the ODWO for THMs and aluminum residual, and will be more capable of achieving a turbidity in the filter effluent of 0.1 NTU:

1. An acid feed system should be installed to provide independent and automatic control over pH. Either sulfuric acid or carbon dioxide can be used for pH adjustment. Addition of an acid feed system would allow using straight alum all year around. This would improve the overall coagulation/flocculation process. There is an existing pH meter installed on the raw water line, but the system should include a permanent pH monitoring set-up with a smaller sample basin to reduce the lag time in obtaining results.
2. A back-up pH monitoring system at least in storage would be meaningful given the important nature of this instrument.

3. Installation of a new automatic pH controller for the raw water to help maintain the optimum pH of the raw water after alum injection. The optimum pH would be controlled by addition of either sulphuric acid, CO_2, or caustic soda, depending on the raw water condition. The operation of the acid and caustic soda feeding pumps would be controlled by the on-line pH meter. Injection of alum would be paced on the raw water flowmeter.
4. Installation of a new pH monitoring and control system for the treated water to help maintain a pH of 7.5 to 8.0 in the treated water, for control of corrosion in the distribution system.
5. If required after 1 to 4 completed perform chloramination of the treated water leaving the plant by adding ammonium sulphate at the high lift pump header to stop any further THMs formation in the distribution system. This would insure that THMs levels in the treated water will not exceed 100 µg/L particularly during warm water conditions.
6. The coagulant and disinfection feed systems should have fully functional back-ups to allow quick change-over in the event of a problem.
7. Increase the turn over of the reservoirs located in town to eliminate long contact times and reduce the possibility for THMs formation. This recommendation would not be required if the plant converts to chloramination.
8. This plant is near or sometimes over its hydraulic capacity and a plant expansion will be required in the near future.

The recommended modifications above should be considered for incorporation into any new treatment facility, depending on the chosen water source.

COST ESTIMATE FOR IMPLEMENTATION

The following is a summary of capital expenditure involved for the implementation of the recommended up-grades. The figures presented are preliminary estimates prepared to give an idea of the price range involved.

Capital Cost Estimates

PROPOSED MODIFICATIONS	COST ($)
Acid feed system including piping and accessories.	$8,000
One back-up pH monitoring system for the raw water pH adjustment.	$2,000
One automatic controller for the raw water pH.	$6,000
One new on-line pH monitoring system for the treated water.	$2,000
Ammonium sulphate feed system to perform chloramination of the treated water including two dosing pumps, one day tank and mixer, piping and accessories, and one chlorine analyzer.	$10,000
One back-up dosing pump for the alum dosing system, and one back-up dosing pump for the chlorine dosing system.	$8,000
TOTAL:	**$36,000**

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MOOSONEE SOUTH

WATER TREATMENT PLANT
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1.0 BACKGROUND

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics (e.g. formed by decay of algae and vegetation) in raw water. Surface water containing high organics also often has high colour levels. The most common forms of trihalomethanes created are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.

The formation of THMs is influenced by several factors:

• Free chlorine concentration	- higher Cl_2	= higher THMs
• Organic content	- higher organic concentration	= higher THMs
• pH	- higher pH	= higher THMs
• Temperature	- higher temperature	= higher THMs
• Time	- normally longer time	= higher THMs

Since the formation of trihalomethanes is associated with the presence of organics in the water, small inland lakes and rivers, which may contain more organics than large clear bodies of water have a greater trihalomethane formation potential, especially during periods of high runoff.

The reason for adding chlorine to drinking water is to kill bacteria and other microorganisms that could cause numerous illnesses. However chlorine use leads to the presence of trihalomethanes and this is a cause for concern. Studies have found an association between high levels of trihalomethanes in chlorinated drinking water, and slight increases in cancer following long term exposure of more than 35 years.

Chlorine has an advantage over other disinfectants in that it persists many hours or for days and provides protection for the entire water distribution system. The benefit to public health of using chlorine as a disinfectant in drinking water far out-weighs the risk to health associated with the low levels of trihalomethanes created as by-products of chlorination.

In order to decrease the health risk from trihalomethanes, the Canadian and Ontario governments have lowered their respective guideline limits from a maximum acceptable concentration of 350 μg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 μg/L based on a running annual average of four quarterly samples.

Disease outbreaks caused by giardia and cryptosporidium have been reported with increased frequency over the last decade in Canada and the US. These protozoan parasites (especially) are more difficult to kill than bacteria with disinfectants, and therefore their removal by physical processes is vital. As a result, Health Canada is now examining the need for stricter standards for particle removal in water plants. The current Ontario Drinking Water Objective (ODWO) for turbidity that applies at the water treatment plant is 1 NTU, but current US research and experience now indicates that a filter effluent turbidity of 0.1 NTU is needed to provide protection from cryptosporidium. In the attempt to reduce potential for disease outbreaks, this study attempted to evaluate the feasibility to obtain a turbidity of 0.1 NTU in filter effluent.

Alum (aluminum sulphate) is the most widely used coagulant because it is effective, readily available, and relatively inexpensive. However, under some circumstances, or if not used properly, its use can result in elevated levels of residual aluminum in finished drinking water. An article was published on facts about human health and aluminum in drinking water (Environmental Science and Engineering Magazine, January 1997). The following is a summary of the major facts presented in the article.

In recent years, increased attention has been focused on possible adverse effects of aluminum in drinking water on human health. Several epidemiological studies have reported a slightly increased incidence of dementia in communities where drinking water is high in aluminum and these studies have raised concerns among the media and public. A number of theories on the causes of Alzheimer's disease have been proposed and are currently under investigation. From what we know at this time, the evidence linking aluminum and Alzheimer's disease is far from conclusive, but we also cannot be sure that there is no relationship. Humans are constantly being exposed to aluminum via food, air, and water. Ninety percent (90%) of aluminum intake is from food. In general, exposure to aluminum from drinking water is very low (below 3%) compared with that from food and drugs. At the present time the ODWO for aluminum in drinking water is 100 ug/L, which is an operational not health related guideline.

Owners of water treatment plants and water distribution systems who provide water for consumption have legal responsibilities, which are shared by all suppliers of food or drink. Owners and suppliers must take reasonable measures to ensure the water is fit for safe consumption.

This optimization study is funded by the Ontario Ministry of the Environment (MOE), and is a cooperative public/private project between the MOE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities with a conventional water treatment plant (i.e. coagulation, flocculation, settling, filtration and disinfection) in many cases should be capable of producing water that meets the new THMs objective, and also be capable of improved particle removal, without resorting to costly upgrades. The optimization of a water treatment plant consists of:

- Documentation of existing facility.
- Assessment of the performance of each process unit.
- Verification of the hydraulic loading on each process.
- Laboratory jar testing to determine the best combination of treatment chemicals and the optimum dosages to achieve maximum removal of particulates and dissolved organic material, as well as a minimum level of aluminum residual in the treated water.
- Make required changes to plant operation at full-scale to ensure that changes will minimize the formation of THMs, but will not compromise the disinfection requirement.

2.0 OBJECTIVES

The two main objectives of the study are:

1. IMPROVEMENT OF THE MOOSONEE SOUTH WATER TREATMENT PLANT PERFORMANCE

- Improve plant performance without major capital/equipment expenditures. Specific water quality objectives are listed below in decreasing order of priority:

  i To comply with the 100 µg/L ODWO for THMs in treated water as a running annual average of 4 quarterly samples. This objective shall be met while ensuring proper removal and/or inactivation of disease-causing microorganisms such as bacteria and viruses, since this remains the most critical aspect of drinking water treatment.

  ii To improve particulate removal to reduce or eliminate disease risk from giardia and cryptosporidium. While the ODWO for turbidity is 1.0 NTU, the goal is to achieve 0.1 NTU in the filter effluent.

  iii To keep aluminum residual at or below 100 µg/L to meet the ODWO.

2. SUSTAINING LONG-TERM PERFORMANCE

- Skills transfer to plant operating staff to enable them to effectively control and adjust processes over the long term in response to raw water quality variations.

- Documentation of plant conditions with recommendations for up-grades and operational modifications.

3.0 DOCUMENTATION OF EXISTING CONDITIONS

The original water treatment plant was built in 1964 and expanded in 1984. The plant is owned by the Moosonee Development Area Board, and is presently operated by the Ontario Clean Water Agency (OCWA). The plant services a population of approximately 2,000. There are three operators on staff responsible for the operation of two water treatment plants and two sewage treatment plants in the community. A plant survey was performed during a site visit on May 22 and 23 1996 to prepare a detailed description of the existing equipment and the condition of operation. The survey is documented in Appendix A. A plant schematic is presented in Figure 3.1.

The raw water characteristics are:

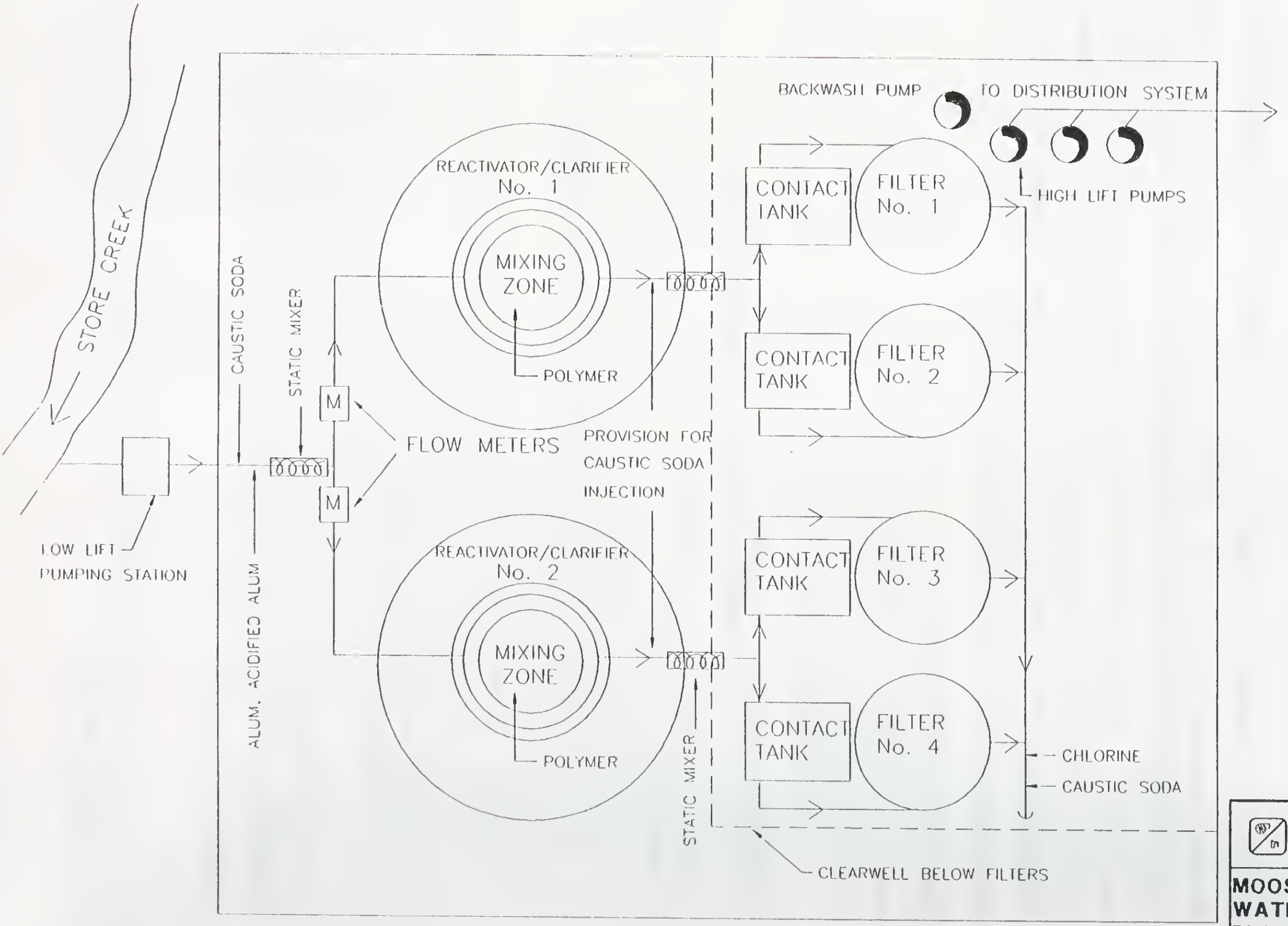
Colour:	40 to 300 TCU
Turbidity:	2 to 30 NTU
pH:	7.1 to 8.0
Alkalinity:	25 to 312 mg/L

Plant flows are generally:	Average day	935 m^3/d (650 L/min)
	Maximum daily flow	1,080 m^3/d (750 L/min)

The water treatment plant consists of:

- ⇒ Low lift pumping station drawing raw water from Store Creek.
- ⇒ Raw water supply main to the treatment plant.
- ⇒ Coagulant feed systems for alum or acidified alum, caustic soda and polymer.
- ⇒ Two (2) Graver Reactivators/clarifiers.
- ⇒ Four (4) contact tanks, intended for intermediate pH adjustment.
- ⇒ Four (4) dual media filters.
- ⇒ One (1) clearwell storage located under the filter area.
- ⇒ Chlorine and caustic soda injection at the filter effluent.
- ⇒ Three (3) vertical turbine high lift pumps.

The plant is in operation 24 hours per day 365 days a year. The plant is near or sometimes over its capacity. Operating pressure in the distribution system is maintained at a maximum of 275 kPa (40 psi) to reduce water consumption.



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**MOOSONEE SOUTH
WATER TREATMENT
PLANT SCHEMATIC**

3.1 THE TREATMENT PLANT PROCESS

Two Graver Reactivators units are operated in parallel. Each Reactivator unit contains a central baffled mixing zone for flocculation and a solids contact clarifier discharging the supernatant to four contact tanks. The contact tanks are operated in parallel and were originally installed to give the flexibility to do recarbonation after lime softening, or pH adjustment after colour removal with alum in the clarifier. Water softening has never been performed at the plant, and it was found that pH adjustment after alum addition for colour removal has not been implemented. Therefore, no chemicals are added to the contact tanks, and they are currently used to provide additional contact time before the filters. Four dual media filters are operated in parallel and installed in a steel tankage. The filter effluent is discharged into a one-celled clearwell containing baffles interconnected to the high lift pumps. The clearwell is located below the filter area. The filters are backwashed with a separate pump.

A process unit model is as follows:

MIXING	**2 CLARIFIERS**		**4 CONTACTS TANKS**		**4 FILTERS**	
	Reactivator #1					
	D - External	4.30 m	L	0.67 m	DIAM	1.83 m
	D - Internal	1.90 m	W	0.67 m		
	DEPTH	3.60 m	DEPTH	3.40 m		
	AREA	11.7 m^2	AREA	0.45 m^2	AREA	2.6 m^2
	VOL	42.1 m^3	VOL	1.5 m^3		
	Reactivator #2					
STATIC MIXER	D - External	4.60 m				
	D - Internal	1.90 m				
	DEPTH	3.80 m				
	AREA	13.8 m^2				
	VOL	52.4 m^3				
	Total Area	25.5 m^3				
	Average Rise Rate	1.8 m/h				
	Average Retention Time	123.0 min	RETENTION TIME	8 min	FILTRATION RATE	4.3 m/h

MOE GUIDELINE

1000 s-1	Min.	1.6	m/h		Recom.	9	m/h
	to	2.4	m/h		Max.	12	m/h

A description of the process unit operations associated with the plant is as follows:

3.1.1 Rapid Mixing

There is a static in-line mixer installed on the raw water line before the two Reactivators, immediately after the injection points for alum or acidified alum (depending on the raw water characteristics), and caustic soda for alkalinity adjustment. Adequate mixing energy is provided for dispersion of the coagulant. Coagulants react (hydrolyze) in water very quickly. In order to be effective the chemical must be mixed rapidly and thoroughly to come in contact with all of the raw water during this critical stage. The MOE guideline for rapid mix is for an energy gradient of 1000 s^{-1} (Ontario Ministry of the Environment, 1982). Polymer is added to the mixing zone of the Reactivators.

3.1.2 Mixing Zone

The mixing zone is equipped with a variable speed mechanical flocculator. The mechanical flocculators are operated at the lowest speed range to avoid shearing of floc.

3.1.3 Sedimentation

The sedimentation process consists of two Graver Reactivator/clarifiers. The first Reactivator was installed during the initial construction of the plant in 1964, and the second unit was installed during the plant up-grade in 1984. The dimensions of the two Reactivators are summarized as follows:

Reactivator No.1:	4.3 m diameter x 3.6 m depth
Reactivator No.2:	4.6 m diameter x 3.8 m depth

Flow to the two Reactivators is adjusted manually to try and equalize the hydraulic rise rate (ie. more flow is directed to Reactivator No. 2 than No. 1 due to the larger surface area). The mixing zone installed in the center of each clarifier has a diameter of 1.9 m. The Reactivators are designed to be operated as solids contact clarifiers.

The average rise rate for the Reactivators No.1 and No.2 is 1.8 m/hr at the maximum day flow (1,080 m^3/d). The MOE guideline for sedimentation tank rise rate is 1.6 to 2.4 m/h but is qualified that this rate should be reduced for cold coloured waters.

3.1.4 Contact Tanks

One contact tank is installed prior to each filter for a total of four contact tanks. The dimensions of each tank are summarized as follows:

- Length and Width: 0.67 m
- Depth: 3.4 m
- Volume: 1.5 m^3
- Contact time: 8 minutes at maximum day demand (1,080 m^3/d)

In the 1984 plant expansion it was proposed to switch to lime softening treatment in the winter. The contact tanks were installed to provide contact time for re-carbonation of the water. To this date lime softening has never been performed at the plant due to a concern for the switch-over transition period and the handling requirements for lime. Another function of the tanks was to provide additional contact time for pH adjustment of the water after alum treatment for colour removal, however, this has not been implemented.

3.1.5 Filtration

The four dual media filters are operated at a filtration rate of 4.3 m/h at maximum day flow. This compares to the MOE recommended rate of 9 m/h for a plant of this size and type. There is a separate backwash pump drawing from the clearwell. Effluent from the filters is discharged to the clearwell located below the filter floor.

3.1.6 Clearwell and Reservoirs

The clearwell consists of one cell with baffles, installed in the 1984 up-grade. The baffles are made of fiberglass and were installed to improve the contact time and reduce short-circuiting. The overall dimensions of the clearwell are 8.5 m x 11.1 m x 2.4 m deep, for a total volume of 226 m^3 (50,000 IG).

There are two reservoirs and an associated pumping station in the north end of town that are used to maintain the pressure in the distribution system and to provide additional storage. The reservoirs are installed above ground and are made of concrete. The total volume for the two reservoirs is 1,136 m^3 (250,000 IG).

3.1.7 High Lift Pumps

There are three vertical turbine pumps at the plant with a capacity of approximately 500 L/min each. There were no issues related to high lift pumping.

3.1.8 Wastewater Disposal

The wastewater generated from the clarifier blowdown and the filter backwash are discharged to the creek downstream of the raw water intake.

3.2 CHEMICAL FEED SYSTEMS

The chemical feed systems used at the plant are summarized as follows:

Process Function	*Chemical*	*Locations Added*
Primary coagulant	Liquid alum or acidified alum	In-line static mixer on the raw water line.
Alkalinity adjustment	Caustic soda	In-line static mixer on the raw water line.
Coagulant aid	LT20 polymer	Into the mixing zone of Reactivators.
Disinfection	Sodium Hypochlorite	Filter effluent
pH Adjustment	Caustic soda	Filter effluent.

The water treatment plant is not pre-chlorinating.

3.2.1 Alum and Acidified Alum

Highly variable raw water quality ranging from high colour and relatively low alkalinity, during rainy weather and runoff conditions, to moderate colour and high alkalinity, during the winter, are experienced at the plant. These conditions can change drastically in a matter of hours.

At times, the process requires pre-alkalinity feed to react with alum, and other times, mainly during the winter, the process needs an acid to depress pH. The plant currently uses one of three acidified alum based coagulants (A-10, A-15 and A-20), or the regular grade liquid alum. The alum dosage during the summer is approximately 170 mg/L, and the dosage of acidified alum during the winter is approximately 110 mg/L. The primary coagulant is added before the in-line static mixer on the raw water line.

3.2.2 Polymer Feed

The coagulant aid used at the plant is LT20 or LT24 polymer depending on the time of the year. The dosage varies between 0.5 to 1 mg/L. The polymer solution is fed directly into the mixing zone of the Reactivator.

3.2.3 Caustic Soda

A caustic soda solution is prepared at the plant from a dry powder supply. Caustic soda is added prior to the in-line static mixer in the raw water line for alkalinity adjustment to react with alum. At times, caustic soda is fed with acidified alum to achieve an adequate pH balance. Caustic soda is also added to the filter effluent to increase the pH of the treated water. The effluent pH was maintained at 7.9 during the summer of 1996, and at 7.2 during the summer of 1997.

3.2.4 Chlorine

A twelve percent (12 %) nominal strength sodium hypochlorite solution is fed into the filter effluent. The applied dosage ranges from 2 to 4 mg/L to maintain a free chlorine residual in the treated water leaving the plant between 0.2 to 0.8 mg/L.

3.3 FLOW MEASUREMENT

There is a turbine flow meter prior to each Reactivator, however, these two flow meters are not functioning and need maintenance and calibration, or replacement. The treated water flow is measured by a turbine flow meter with totalizer.

3.4 HISTORICAL DATA – February to August 1994

A summary of historical data from February to August 1994 summarizing concentrations for turbidity, colour, pH, alkalinity and THMs (1994 to 1996) found in the raw and the treated water is presented below. The water samples were analyzed by the Ministry of the Environment.

Table 3.1 Moosonee South WTP Monthly Average Water Quality Results for 1994

Parameters	*Units*	*Raw Water*	*Treated Water*
Turbidity	NTU	2.3 to 13.6	0.4 to 11.9
Colour	TCU	37 to 194	10 to 18
pH		7.16 to 8.04	7.1 to 8.09
Alkalinity	mg/L-$CaCO_3$	25 to 312	31 to 226
THMs-Plant Effluent	µg/L		93 to 226
THMs-Distribution System	µg/L		42 to 171

Historical data for 1994 showed highly variable raw water quality ranging from high colour and relatively low alkalinity (wet weather/runoff conditions) to moderate colour and high alkalinity (winter conditions). These conditions were confirmed through the sampling and analysis performed in 1996 and 1997.

The colour level in the treated water for 1994 ranged between 10 to 18 TCU for an average of 13 TCU, which is above the Ontario Drinking Water Objective of 5 TCU. However results in 1996 and 1997 were significantly improved with values generally below 5 TCU.

The treated water turbidity in 1994 was high peaking up to 11 NTU. In 1996 and 1997 however there was a significant improvement with turbidities generally below 1.0 NTU but still above the study objective of 0.1 NTU.

High levels of THMs were observed in February 1994 with 226 μg/L at the water treatment plant. High THMs levels in excess to the new guideline were also measured in the distribution system in August 1995 and July 1996 with concentrations of 135 and 171 μg/L respectively. It is expected that with some improvement in TOC removal, THMs can be reduced to within acceptable limits.

4.0 PERFORMANCE ASSESSMENT

4.1 1996 WATER SAMPLING

Water samples were collected at the treatment plant in July and September 1996 to establish a baseline for THMs versus the level of colour and total organic carbon (TOC). Novamann (currently operating under Maxxam Analytics) analyzed the samples. The results obtained from 5 weeks of sampling are summarized in Table 4.1. The operation data collected at the plant for the days of sampling including average daily flow, turbidity, raw water temperature and chemical dosages are presented in Table 4.2.

The parameters exceeding the Ontario Drinking Water Objectives (ODWO) for the 1996 water sampling are summarized as follows:

- The raw water turbidity varied from 2.8 to 8.5 NTU. The average treated water turbidity was quite variable and ranged from 0.2 to 1.4 NTU for an average of 0.6 NTU. The turbidity exceeded the ODWO of 1 NTU for one sample, but the average turbidity significantly exceeded the study objective of 0.1 NTU.
- The raw water colour varied from 97 to 122 TCU. The treated water colour varied from 3 to 7 TCU, for an average of 5 TCU. The colour of the treated water was variable and exceeded the ODWO of 5 TCU for 2 samples.
- The total organic carbon in the raw water ranged from 13.4 to 18.3 mg/L. TOC levels in the treated water varied from 3.9 to 6.5 mg/L, for an average of 5.2 mg/L. Assuming that the level of TOC is representative of the dissolved organic carbon (DOC) concentration in the water, the TOC in the treated water exceeded 5 mg/L for 3 samples.

- The THMs measured in the distribution system varied from 13 to 320 µg/L, for an average of 130 µg/L. The THMs during the summer of 1996 exceeded the new ODWO of 100 µg/L for 3 water samples. THMs were in excess of the new guideline in July and August, but may not be over the annual quarterly average. The level of THMs is normally higher during the summer due to higher water temperature. Sampling performed by the MOE for the Drinking Water Surveillance Program (DWSP) showed lower levels of THMs in compliance with 100 µg/L for the fall, winter and spring. It is expected that with some improvement in TOC removal, THMs can be reduced to within acceptable limits.

The water samples taken in the distribution system for THMs analysis were quenched with sodium thiosulfate to remove any chlorine residual to stop further reaction between free chlorine and organics. Quenched water samples will maintain the same level of THMs as existed at the time of sampling representing the quality experienced by the consumer. The water samples taken at the water treatment plant for THMs analysis were not quenched, the reason being to simulate the effect of additional contact time in the distribution system versus the development of THMs.

Based on THMs, colour and TOC analysis performed for the Moosonee South Water Treatment Plant, there is no evidence of a direct relation between the level of colour or TOC in the water and the level of THMs formed. The lack of THM-colour correlation is somewhat unexpected since in general the higher the colour, the higher the organic content, therefore producing higher THMs. In addition to the limited number of samples collected, other factors which may have contributed to the lack of correlation include the relatively narrow range of colour value observed, and the analytical variability for THMs analysis. The detection limit of the analytical procedures and the method reference used by Novamann (Maxxam Analytics) is summarized in Appendix D.

Generally, the plant staff is keeping up with the process and is producing good quality water. Specifically there has been a tremendous improvement over the past year or more, due to the efforts of the Ontario Clean Water Agency (OCWA) operating staff.

An option available to further reduce the formation of THMs is to perform chloramination. Chloramine does not react with organics to form THMs. Chloramines are more stable than free chlorine and maintain a longer-lasting residual in the distribution system. Chloramination can be done by adding ammonium sulphate to the water leaving the plant. Ammonium sulphate will combine with free chlorine to form chloramines. Chlorine would still be added to the filter effluent to provide disinfection with free chlorine in the clearwell.

Eight additional samples of plant effluent were collected in September and October 1996 on four separate occasions. Four of the samples were quenched (stopping any further reaction with chlorine) to simulate THMs formation that would occur if chloramination of the water leaving the plant was implemented. THMs formation ceases when ammonium reacts with free chlorine. Four samples were not quenched. The results are summarized as follows:

Parameters	***Units***	***Range***	***Average***
THMs - Treated Water Quenched:	μg/L	66 to 110	92
THMs - Treated Water Unquenched:	μg/L	110 to 190	143

The level of THMs formed in the unquenched water leaving the plant varied from 110 to 190 μg/L, which simulates the THM levels that would occur in the far reaches of the distribution system. THMs levels in quenched treated water (simulating chloramination) varied from 66 to 110 μg/L for an average of 92 μg/L. It is therefore expected that the THMs level can be maintained below 100 μg/L in the distribution system by performing chloramination.

TABLE 4.1 JULY AND AUGUST 1996 SAMPLING FOR MOOSONEE SOUTH WATER TREATMENT PLANT WATER SAMPLES ANALYZED BY NOVAMANN

PARAMETERS	WEEK 1 (10/07/96)	WEEK 2 (16/07/96)	WEEK 3 (24/07/96)	WEEK 4 (04/09/96)	WEEK 5 (10/09/96)	MINIMUM	MAXIMUM	AVERAGE
Turbidity - Raw Water (NTU)	2.8	3.2	3.6	3.2	8.5	2.8	8.5	4.3
Turbidity - Treated Water (NTU)	0.7	0.3	0.2	0.5	1.4	0.2	1.4	0.6
Colour - Raw Water (TCU)	114	122	118	111	97	97	122	112
Colour - Treated Water (TCU)	3	5	5	6	7	3	7	5
Colour - Distribution System (TCU)	2	5	7	7	7	2	7	6
pH - Raw Water	8.0	7.8	7.8	8.0	8.0	7.8	8.0	7.9
pH - Treated Water	8.3	7.9	8.1	7.9	7.9	7.9	8.3	8.0
Alkalinity - Raw Water (mg/L - $CaCO_3$)	40	60	87	111	141	40	141	88
Alkalinity - Treated Water (mg/L - $CaCO_3$)	32	50	72	87	116	32	116	71
TOC - Raw Water (mg/L)	17.3	13.4	15.3	18.3	17.1	13.4	18.3	16.3
TOC - Treated Water (mg/L)	4.2	3.9	5.1	6.2	6.5	3.9	6.5	5.2
TOC - Distribution System (mg/L)	4.1	4.9	4.8	6.2	6	4.1	6.2	5.2
TTHMs - Unquenched Treated Water (ug/L)	140	110	150	110	130	110	150	128
TTHMs - Quenched Distribution System (ug/L)	320	77	130	110	13	13	320	130

TABLE 4.2 JULY AND AUGUST 1996 SAMPLING FOR MOOSONEE SOUTH WATER TREATMENT PLANT OPERATION DATA COLLECTED AT THE WTP

PARAMETERS	WEEK 1 (10/07/96)	WEEK 2 (16/07/96)	WEEK 3 (24/07/96)	WEEK 4 (04/09/96)	WEEK 5 (10/09/96)	MINIMUM	MAXIMUM	AVERAGE
Average Daily Flow (m^3/d)	1,008	1,264	1,008	909	951	909	1,264	1,028
Turbidity - Raw Water (NTU)	38	36	34	36	32	32	38	35
Turbidity - Treated Water (NTU)	1	0	0	1	0	0	1	0
Temperature - Raw Water (Degree Celsius)	10	16	16	15	14	10	16	14
Free Chlorine Residual (mg/L)	1.2	0.2	0.5	0.4	0.2	0.2	1.2	0.5
Total Chlorine Residual (mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alum Dosage (mg/L)	176	176	186	153	149	149	186	168
Coagulant Aid Dosage - LT20 (mg/L)	1.2	1.2	1.2	0.5	0.5	0.5	1.2	0.9
Caustic Soda (mg/L)	40	41	40	11	11	11	41	28
Sodium Hypochlorite Dosage (mg/L)	N/A	N/A	1.9	3.1	4.0	1.9	4.0	3.0

N/A: Not Available

4.2 1997 WATER SAMPLING

The 1997 summer sampling was performed over a 5-week period for a total of 10 samples taken from July to August 1997. The results are summarized in Table 4.3. Operating data collected at the plant during the day of sampling are summarized in Table 4.4. The parameters exceeding the ODWO are summarized as follows:

- The raw water turbidity ranged from 2.8 to 5.9 NTU. The treated water turbidity varied from 0.4 to 2.5 NTU, for an average of 0.9 NTU. The level of turbidity exceeded the ODWO of 1 NTU for 1 of the 10 samples and was again quite variable and well over the study objective of 0.1 NTU.

- The raw water colour ranged from 50 to 75 TCU, and the treated water colour varied from 1 to 6 TCU, for an average of 4 TCU. The colour of the treated water exceeded the ODWO of 5 TCU for 2 samples.

- The total organic carbon ranged in the raw water from 7.6 to 18.6 mg/L. The TOC in the treated water varied from 2.2 to 6.9 mg/L, for an average of 4.8 mg/L. The TOC in the treated water exceeded 5 mg/L for 7 water samples.

- The THMs measured in the distribution system varied from 67 to 130 μg/L, for an average of 80 μg/L. The THMs level during the summer 1997 exceeded the new ODWO of 100 μg/L for only one of the 10 samples. The level of THMs was improved in the summer 1997 by maintaining an average pH in the treated water of 7.2, by comparison to a pH of 8.1 for the summer 1996. However, a potential corrosion problem may occur over time in the distribution system by maintaining a lower pH.

- The aluminum level in the raw water varied from 98 to 599 µg/L. The residual aluminum in the treated water ranged from 83 to 1,210 µg/L, for an average of 328 µg/L. The aluminum residual exceeded the interim ODWO of 100 µg/L for 9 of the 10 water samples.

Additional analyses were performed to evaluate the level of Haloacetic Acids (HAAs) in the treated water. HAAs are by-products of disinfection with chlorine reacting with humic substances. Currently, there is no guideline in Ontario regulating the maximum level of HAAs in drinking water.

The formation of HAAs increases as pH decreases. Lowering the pH in the treated water (as in 1997) will reduce the formation of THMs but will increase the level of HAAs. Samples were taken in the distribution system and were quenched with ammonium chloride to stop any further formation. The level of HAAs in the distribution system varied from 22 to 96 µg/L for an average of 63 µg/L. This could be considered as a 'worst case' scenario for HAAs at Moosonee under normal operation, since the plant would never be operated at a pH lower than what was experienced in 1997.

Caustic feed, used for pH adjustment for corrosion control, was moved from the clearwell inlet to the clearwell outlet midway through the sampling period to keep the clearwell pH low. This did not have an impact of THMs levels in the distribution system. However, it does allow a lower free chlorine residual to be used for disinfection.

TABLE 4.3 JULY AND AUGUST 1997 SAMPLING FOR MOOSONEE SOUTH WATER TREATMENT PLANT WATER SAMPLES ANALYZED BY MAXXAM ANALYTICS

PARAMETERS	WEEK 1 (14/07/97)	WEEK 1 (16/07/97)	WEEK 2 (21/07/97)	WEEK 2 (23/07/97)	WEEK 3 (28/07/97)	WEEK 3 (30/07/97)	WEEK 4 (04/08/97)	WEEK 4 (06/08/97)	WEEK 5 (11/08/97)	WEEK 5 (13/08/97)	MINIMUM	MAXIMU	AVERAGE
Turbidity - Raw Water (NTU)	5.0	4.6	4.9	5.4	5.8	4.1	4.3	4.6	5.9	2.8	2.8	5.9	4.7
Turbidity - Treated Water (NTU)	0.4	0.6	1.0	0.5	0.5	1.0	2.5	0.9	0.8	0.7	0.4	2.5	0.9
Colour - Raw Water (TCU)	50	56	74	75	64	69	53	56	57	52	50	75	61
Colour - Treated Water (TCU)	2	6	4	4	1	4	6	4	4	4	1	6	4
pH - Raw Water	7.9	7.9	7.7	7.9	7.9	8.0	7.8	7.9	7.9	7.9	7.7	8.0	7.9
pH - Treated Water	7.5	7.5	7.1	7.2	7.3	6.9	7.2	7.1	7.3	7.3	6.9	7.5	7.2
Alkalinity - Raw Water (mg/L - $CaCO_3$)	115	110	107	112	145	135	150	156	165	175	107	175	137
Alkalinity - Treated Water (mg/L - $CaCO_3$)	77	84	64	74	99	69	84	84	106	89	64	106	83
Aluminum - Raw Water (ug/L)	99	147	165	174	148	139	104	98	132	599	98	599	181
Aluminum - Treated Water (ug/L)	83	132	320	300	169	225	1,210	300	238	307	83	1,210	328
TOC - Raw Water (mg/L)	13.9	16.2	7.6	18.6	13.7	15.0	14.4	15.9	13.0	13.1	7.6	18.6	14.1
TOC - Treated Water (mg/L)	5.5	2.4	2.2	2.2	5.1	5.1	6.8	6.4	5.8	6.9	2.2	6.9	4.8
TTHMs - Unquenched Treated Water (ug/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-
TTHMs - Quenched Dist. Syst. North (ug/L)	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13	-	-
TTHMs - Quenched Dist. Syst. South (ug/L)	74	68	70	87	130	71	79	67	67	83	67	130	80
HAAs - Quenched Dist. System (ug/L)	44	22	50	53	92	84	96	82	55	55	22	96	63

Caustic feed at clearwell inlet.

Caustic feed changed to clearwell outlet, no effect on THMs in distribution system.

NOTE: N/A: Not Available

TABLE 4.4 JULY AND AUGUST 1997 SAMPLING FOR MOOSONEE SOUTH WATER TREATMENT PLANT OPERATION DATA COLLECTED AT THE WTP

PARAMETERS	WEEK 1 (14/07/97)	WEEK 1 (16/07/97)	WEEK 2 (21/07/97)	WEEK 2 (23/07/97)	WEEK 3 (28/07/97)	WEEK 3 (30/07/97)	WEEK 4 (04/08/97)	WEEK 4 (06/08/97)	WEEK 5 (11/08/97)	WEEK 5 (13/08/97)	MINIMUM	MAXIMU	AVERAGE
Average Daily Flow (m^3/d)	931	973	981	969	998	1,055	1,139	1,055	948	983	931	1,139	1,003
Turbidity - Raw Water (NTU)	3.7	4.6	7.1	6.8	4.3	5.0	4.4	4.7	4.8	4.7	3.7	7.1	5.0
Turbidity - Treated Water (NTU)	0.4	0.8	0.9	0.7	0.3	0.3	1.8	0.8	0.5	0.6	0.3	1.8	0.7
pH - Treated Water	7.0	7.0	7.2	7.0	6.9	6.9	6.8	7.0	7.0	7.0	6.8	7.2	7.0
Temperature - Raw Water (Degree Celsius)	17	18	13	13	19	16	14	14	15	13	13	19	15
Free Chlorine Residual (mg/L)	0.3	0.2	0.6	0.7	0.5	0.8	0.6	0.6	0.4	0.4	0.2	0.8	0.5
Total Chlorine Residual (mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-
Alum Dosage (mg/L)	179	161	179	188	174	174	172	170	185	182	161	188	176
Coagulant Aid Dosage - LT20 (mg/L)	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.5	0.5
Caustic Soda (mg/L)	24	22	20	20	19	19	18	16	18	18	16	24	19
Post Sodium Hypochlorite Dosage (mg/L)	3.0	3.0	3.1	3.2	2.9	2.9	2.9	3.8	4.2	3.1	2.9	4.2	3.2

N/A: Not Available

4.3 PROCESS UNIT ASSESSMENT

The water treatment plant is at its hydraulic capacity mainly due to the limitations of the clarifiers. The plant reaches its maximum capacity during February and March from the bleeding that is done by residents to keep piping from freezing. A way to mitigate this problem was to lower the operation pressure in the distribution system to 275 kPa (40 psi), which created other operational problems related to low pressure in households particularly for two-story houses.

4.3.1 Mixing

Chemical mixing is provided by an in-line static mixer installed in the raw water line immediately after the alum and caustic soda injection points. This provides adequate mixing of treatment chemicals.

4.3.2 Flocculation

The Reactivators are provided with a mixing zone to promote coagulation/flocculation. The polymer is added directly into the mixing zone. The input energy is higher than required but there is allowance for varying flocculator speed to adjust for conditions such as temperature and flow. The variable speed motor is normally set to the lowest speed to reduce shearing of flocs, typical of coagulation of raw water high in colour.

4.3.3 Clarification

The rise rates in the clarifers No.1 and No.2 are within the MOE guideline, however, the MOE recommends lower rates under the conditions of cold highly coloured water as occurs in Moosonee. These units are not performing well. It is very difficult to maintain a sludge blanket in the clarifiers due to the small floc formation often typical of high coloured water with relatively low turbidity. The clarifiers are therefore operated as sedimentation tanks most of the time. A longer residence time and lower rise rate would be required to settle the floc. Floc carry over onto the filters is frequently observed reducing the filtration time between backwashs. The Reactivators are currently operated at their maximum practical capacity and are a limiting factor in the treatment capacity of the plant.

4.3.4 Filtration

The filtration rate of the four filters is very conservative and should be capable of efficient turbidity removal. The filtration process would be greatly improved by improving solids settling in the clarifiers to reduce floc carry over.

4.3.5 Disinfection

Disinfection of drinking water is the most important aspect of the treatment process. Harmful organisms in water such as bacteria, viruses or cysts can cause illness ranging from minor intestinal disorders to potentially fatal infections. Maintaining an effective disinfection system must be the overriding priority of the plant operations. For surface waters, chlorination with a 'free' residual is the most common and most practical method of disinfection. To be effective, the treated water must be very low in turbidity as suspended particles can shield bacteria and viruses from the effects of chlorine. Turbidity levels greater than 0.1 NTU indicate an increased probability of chlorine resistant cysts being present.

To achieve a safe level of disinfection, it is necessary to dose the treated water with a sufficient amount of chlorine to produce a 'free' residual, and to give the free chlorine sufficient time to inactivate the potentially harmful organisms. This is called the concentration-time factor or CT, also referred to as the primary disinfection stage. Sufficient CT must be achieved at the treatment plant before the first service connection. Current MOE guidelines call for a minimum residual of 0.5 mg/L for a minimum contact time of 30 minutes after filtration. This disinfection guideline for water treatment plants in Ontario is under review, and the new guideline may be similar to the Surface Water Treatment Rule (SWTR) promulgated by U.S. Environmental Protection Agency (U.S. EPA). The SWTR established CT values for free chlorine, chlorine dioxide, ozone and chloramines required to achieve adequate inactivation of giardia cysts and viruses. For the purpose of calculating CT value, T is the time (in minutes) it takes the water, during peak plant flows, to move between the point of disinfectant application and a point where, C, residual disinfectant (in mg/L) concentration is measured just prior to the first customer. The calculation must account for the degree of short circuiting in the storage tank.

For free residual chlorination, the CT required is based on the inactivation of giardia cysts in cold water. Giardia cysts are harder to inactivate by free chlorine than viruses, therefore, it is implied that proper inactivation of giardia cysts will ensure inactivation of viruses. Disinfection with chlorine is not effective for the inactivation of cryptosporidium. Therefore, it is necessary to perform adequate filtration at the water treatment plant for any municipality at risk of cryptosporidium outbreaks.

Secondary disinfection refers to the maintenance of a residual in the distribution system to protect against bacterial re-growth or minor cross connection contamination. This maintenance residual is commonly achieved with 'free' chlorine, but alternatively can be converted to chloramine or 'combined' residual with the addition of ammonia. Chloramines have the advantage of being more stable and lasting much longer in the system. They also do not react with organics to form THMs. They are however much less effective as a disinfectant and are very weak in inactivating viruses and cysts. Use of chloramine as a primary disinfectant is therefore not recommended.

The MOE guidelines recommend a chlorine residual should be maintained in all parts of the distribution system. The AWWA recommends a residual of 1.0 mg/L of chloramine be maintained to prevent bacterial re-growth (AWWA, 1993).

According to the SWTR, all community and non-community public water systems which use a surface water source or a ground water under the direct influence of a surface water must achieve a minimum of 99.9 percent (3-log) removal and/or inactivation of giardia cysts. According to these guidelines, systems with sewage and agricultural discharges to the source water should provide treatment to achieve an overall 99.999 percent (5-log) removal/inactivation of giardia cysts, while the minimum required 3-log removal/inactivation is sufficient for sources with no significant microbiological contamination from human activities, a 4-log removal/inactivation of cysts should be provided for source waters whose level of microbiological contamination is between these two extremes.

There is no sewer discharge up-stream of the raw water intake or agricultural activity near the Store Creek. Therefore, the disinfection requirement will be calculated for a 3-log removal/inactivation of giardia cysts. Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts. The required CT will be based on 0.5-log inactivation of giardia cysts (3.0-2.5-log).

Examples of CT calculations for water temperature of 0.5, 5, 10 and 15 °C are presented in Appendix E. The contact time (T) in the clearwell is estimated by using the maximum daily flow (1,080 m^3/d), when the reservoir is half full. This will reflect the situation at the plant where the process units are producing the maximum daily flow, and the high lift pumps are pumping at peak hourly rate to the distribution system.

Based on the "Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Source" (U.S. EPA, 1990), the baffle condition in the clearwell expressed as T_{10}/T factor can be evaluated to estimate the effective contact time in the clearwell. This factor represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to pass through the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mix chamber.

When tracer studies are not available, a description of the clearwell and baffling condition can be used to estimate the T_{10}/T factor. The clearwell is made of one cell basin with overall dimensions of 8.5 m x 11.1 m x 2.4 m deep. Fiberglass baffles were installed during the 1984 up-grade to improve the effective residence time by reducing short-circuiting. The clearwell is provided with an inlet, outlet and intra-basin baffles. This clearwell arrangement is qualified as an average baffling condition with a maximum estimate for the T_{10}/T factor of 0.5. The results of the evaluation of residual free chlorine concentration required for inactivation of giardia cysts under various water temperatures are summarized in Table 4.5.

TABLE 4.5 Calculation of minimum residual chlorine concentration necessary for inactivation of giardia cysts

CONDITIONS	Free Residual Chlorine Concentration (mg/L) C
Temperature of the raw water 0.5 °C	0.44
Temperature of the raw water 5 °C	0.31
Temperature of the raw water 10 °C	0.23
Temperature of the raw water 15 °C	0.16

The results presented in Table 4.5 indicate that a higher free chlorine residual is required during the winter since lower water temperature reduces the rate of inactivation. Information collected from the water plant shows that the free chlorine residual is normally maintained between at 0.3 and 0.5 mg/L. Therefore, maintaining a free chlorine residual of 0.5 mg/L under cold water temperature, and 0.3 mg/L for the summer condition is sufficient to provide adequate inactivation of giardia cysts, providing that a minimum free chlorine residual of 0.2 to 0.3 mg/L can be maintained at the end of the distribution system. The post caustic feed, which was relocated from the clearwell inlet to the clearwell outlet during the study, must remain at the outlet to allow the above free chlorine residuals to be used.

5.0 OFF-SITE BENCH SCALE EVALUATIONS

5.1 INTRODUCTION

This study was conducted by the MOE Standards Development Branch. The primary objective of this study was to determine what combination(s) of treatment chemicals could be tried at plant-scale to improve the performance of the Moosonee South water plant in terms of colour and turbidity removal.

This treatability study was conducted using a conventional mode of treatment consisting of coagulation, flocculation, sedimentation and filtration, as per the plant's mode of treatment.

5.2 RAW WATER QUALITY

Bulk raw water samples collected in July 1996 were used for the treatability study. Raw water analytical results are summarized in Table 5.1. The raw water turbidity was low, but the colour was high and varied depending on the season and rainfall within the watershed. Alkalinity drops to low levels when the colour rises, and adjustment is needed when alum is used as the coagulant.

5.3 JAR TEST CONDITIONS

All jar testing was performed at approximately 15°C. Jar testing conditions are summarized in Table 5.2. All jars were subjected to the same general conditions.

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Moosonee South WTP
Table 5.1

Novamann Analytical Results

Parameter	Raw Water
THM Formation Potential (ug/L)	1200
Turbidity (NTU) *	3.2
Colour (TCU)	115
Total Organic Carbon	13.8
Total Alkalinity (as CaCO3)	64.0
Total Hardness (as CaCO3)	74.4
pH *	8.16
Conductivity (umho/cm)	286
Aluminum	0.077
Iron	0.385
Manganese	0.008
Copper	<0.003
Lead	<0.002
Zinc	<0.003
Sodium	29.5
Potassium	1
Calcium	19.8
Magnesium	6.09
Sulphate	5.0
Chloride	41.2
Fluoride	0.3
Nitrate-N	<0.1
Nitrite-N	<0.1
Ammonium-N	<0.05

All units are mg/L unless otherwise noted.

* Results for these parameters are unreliable unless measured at time of sampling.

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Table 5.2

Date: July 19, 1996

TREATABILITY STUDY OBJECTIVE
Optimize treatment for colour and turbidity removal.
Raw Water Source: Store Creek

JAR TEST CONDITIONS			RAW WATER QUALITY	
Treatment Mode:	Conventional		Temperature	15 deg.C
Flash Mix:	Time	1 minute	Alkalinity	70 mg/L
	Speed	100+ rpm	pH	6.93
Flocculation:	Time	20 minutes	Turbidity	4.1 NTU
	Speed	20 rpm	Colour	225 CU
Sedimentation:	Time	30 minutes		(apparent)
Filter Media:	Whatman 541 paper			

CHLORINE DEMAND

Jar #	Cl2 (mg/L)	Free (mg/L)	Total (mg/L)
1			
2			
3			
4			
5			
6			

TTHM FORMATION POTENTIAL

Jar #	Cl2 (mg/L)	TTHM (ug/L)	time/temp
1			
2			
3			
4			
5			
6			

Seven–day Formation Potential Result: 1200 ug/L

ADDITIONAL COMMENTS
Liquid alum added at 190 mg/L with LT20 polymer.
Graver reactivator clarifiers – pH controlled at 6.4–6.5 in effluent.
Chlorine added to clearwell inlet.
Caustic soda added for pre–alkalinity adjustment.

5.4 PRELIMINARY JAR TESTS

Several primary coagulants (aluminum sulphate, polyaluminum chloride and hydroxylated ferric sulphate), and coagulant aids were examined. Preliminary jar test results are summarized in Appendix B (Tables B1 to B11).

5.4.1 Aluminum Sulphate

Aluminum sulphate (alum) was initially applied at dosages that ranged from 80 to 140 mg/L along with the plant's coagulant aid, LT20 polymer, at 0.1 mg/L. The intent was to determine if alum could be applied at dosages low enough to avoid pre-alkalinity adjustment. Results were poor, and it was apparent that a higher alum dosage and pre-alkalinity adjustment would be needed.

In the next run, caustic soda was added at a dosage that resulted in an alkalinity of about 25 mg/L in jar filtrate. Alum was then applied at dosages that ranged from 160 to 210 mg/L along with the plant's coagulant aid, LT20 polymer, at 0.1 mg/L. Based on floc quality, supernatant and filtrate colour, turbidity, and aluminum residual, the optimum alum dosage appeared to be 180 mg/L.

The next run was conducted to see if alkalinity adjustment with sodium bicarbonate could improve treatment. Sodium bicarbonate will raise the alkalinity but not the pH, which should improve the coagulation process. In this run, sodium bicarbonate was added at a dosage that resulted in an alkalinity of approximately 25 mg/L in jar filtrate. Alum was then applied at dosages that ranged from 160 to 210 mg/L along with the plant's coagulant aid, LT20 polymer, at 0.1 mg/L. The resulting turbidity, colour, and aluminum residuals in supernatant and filtrate were very poor. The floc formation, however, was better than the treatment with caustic soda.

In an attempt to improve treated water and floc quality, eight polymers (including LT20) were tried in conjunction with the optimum alum dosage of 180 mg/L and pre-alkalinity adjustment with caustic soda. Alchem 8170 was the best based on floc quality, settling, and water quality. Colour and turbidity reduction was acceptable and the aluminum residual was less than the ODWO operational guideline.

Late in the study, another comparison was made between sodium bicarbonate and caustic soda on 2 jars. Both jars were dosed with alum at 180 mg/L and 8170 polymer at 0.13 mg/L. Once again, the sodium bicarbonate treatment gave very poor supernatant and filtrate quality, but the floc quality was better than caustic soda.

5.4.2 Polyaluminum Chloride

Polyaluminum chloride (PACL - Sternpac) was initially applied at dosages that ranged from 110 to 160 mg/L without a polymer and without alkalinity adjustment. Floc quality was fair, which was expected with no polymer added. Alkalinities in the filtrate ranged from 32 mg/L with the low PACL dosage to 16 mg/L with the high PACL dosage. A 1 mg/L PACL dosage lowered alkalinity by about 0.3 mg/L. This indicates that pre-alkalinity adjustment may not be needed if PACL is used at plant scale. Based on colour, turbidity and aluminum residuals the optimum PACL dosage appeared to be 120 mg/L.

Ten polymers (including LT20) were tried in conjunction with the optimum PACL dosage of 120 mg/L. Eight of these polymers were also tried with alum to enable comparisons to be made. In general, floc quality was similar to that obtained with alum. Turbidities and colours in supernatant and filtrate, and residual aluminum, were much lower than the alum treatments. Based on water and floc quality, Percol LT24 was judged to be the best polymer, 8170 worked well also.

5.4.3 Ferric Sulphate

This primary coagulant (Ferriclear) was tried as an alternative to alum. Ferric sulphate was applied at dosages that ranged from 150 to 200 mg/L without a polymer. Caustic soda was added for adjustment of alkalinity. Results were not conclusive. It was determined that 1 mg/L of Ferriclear lowers alkalinity by 0.58 mg/L.

The run was repeated at 160 to 210 mg/L with LT20 added at 0.13 mg/L. Based on turbidity, colour, and floc quality, the optimum Ferriclear dosage was found to be 200 mg/L.

Six polymers were tried in conjunction with the optimum Ferriclear dosage of 200 mg/L. These six polymers were also tried with alum and PACL. Turbidities and colour in the best jar were similar to the best result for alum, but not as good as the PACL jars. Floc quality was poor.

5.4. Discussion of Results

A comparison between alum and Ferriclear (with best polymers added) showed that alum gave better floc quality. Supernatant and filtrate turbidity and colour were similar. Floc quality is important when trying to settle a colour floc. The optimum dosage for Ferriclear was higher than for alum. It was therefore decided that Ferriclear would not be included in the final runs.

A comparison between alum and PACL (with best polymers added) showed that floc quality is similar, but PACL was much better at removing colour and turbidity, and produced much lower levels of aluminum residual.

It was interesting to see how poor the treatment with alum was when sodium bicarbonate was used. It is believed that the alkalinity added by caustic soda (in the form of hydroxide) is more suitable for coagulation with alum than the bicarbonate ion.

There was not enough water sample remaining to optimize polymer dosages. Past experience has shown that improvements in floc strength and settleability can be realized by doing so.

5.5 FINAL RUNS

During final runs the chemical treatment included post-chlorination. Based on the preliminary jar test results, two chemical treatments were selected for analysis during final runs. Dosages and observations are summarized in Table 5.3. Analytical results are included in Table 5.4.

5.5.1 Aluminum Sulphate

Two 2-L jars were initially dosed with caustic soda to increase the alkalinity, and then treated with alum at a dosage of 180 mg/L and 8170 polymer at 0.13 mg/L. After settling, 1.5 L of supernatant was taken from each jar and combined into one 3-L sample which was filtered. Samples were collected for general chemistry and TOC. The 3-L sample was then chlorinated to obtain a free chlorine residual of 0.5 mg/L ten minutes after chlorine addition. A sample for THMs analysis was collected in 250 mL glass bottles with no headspace, held for 24 hours at 10 °C in darkness to simulate the distribution system. The sample was then quenched with sodium thiosulphate. All the samples were submitted to Novamann for analysis.

5.5.2 Polyaluminum Chloride

Two 2-L jars were treated with PACL at a dosage of 120 mg/L and Percol LT24 polymer at 0.13 mg/L. After settling, 1.5 L of supernatant was taken from each jar and combined into one 3-L sample which was filtered. The 3-L sample was chlorinated to obtain a free residual of 0.5 mg/L ten minutes after chlorine addition. A sample for THMs analysis was collected in 250 mL glass bottles with no headspace, held for 24 hours at 10 °C in darkness, and then quenched with sodium thiosulphate.

5.5.3 Discussion of Results

Real-time measurement of supernatant turbidities and colour in the MOE lab showed that PACL was much better at removing turbidity and colour, which was consistent with the preliminary runs. The performance of alum though was acceptable. Floc quality was similar for both treatments. Novamann results showed that aluminum residuals were above the ODWO of 100 μg/L for the alum treatment, but below the ODWO for PACL. For the alum and PACL treatments, the residuals were significantly higher than those in the preliminary runs. It is not possible to determine if this is a real effect or due to differences between Novamann testing procedure and the Hach DR2000 ECR method used in the MOE lab.

For the alum treatment the level of THMs was 16 μg/L, and for the PACL treatment the THMs level was 30 μg/L. The higher THMs with PACL is surprising given that the TOC level in PACL-treated water was slightly lower than in the alum-treated water. The pH in both samples was nearly the same just prior to chlorine addition.

5.6 CONCLUSIONS

All three primary coagulants evaluated during the treatability study are capable of producing a treated drinking water in compliance with the ODWO.

Ferriclear produced a floc that was poor in comparison with alum and PACL, and at 200 mg/L, did not offer any advantage over alum in terms of operating costs. It was therefore excluded from the final runs.

The optimum alum dosage for the raw water sample used for this treatability study was 180 mg/L. Together with 8170 polymer, the turbidity and colour obtained were acceptable.

The optimum PACL treatment was at 120 mg/L together with Percol LT24. Turbidity and colour removal was excellent.

In general, excellent results were achieved with PACL and LT24 Polymer. PACL was significantly better than alum in producing lower turbidities and lower aluminum residuals in the supernatant. THMs were acceptable but higher than with alum. This result is suspect considering the overall better performance of PACL in removing colour and TOC. PACL is also expected to perform better in cold water and consumes less alkalinity. It is anticipated that a pre-alkalinity feed may not be required however acidification will still need to be practiced.

5.7 RECOMMENDATIONS

A plant trial using PACL together with LT24 polymer should be conducted. This work should answer the following questions:

- Will colour and TOC removal be improved leading to lower THMs?
- Will settling in the clarifier improve and floc carry over decrease, thereby increasing filter run time and consequently saving on treatment costs?
- Will it be possible to eliminate pre-alkalinity adjustment with caustic, thereby simplifying operation and saving on treatment costs?
- Will it be possible to increase the surface overflow rate through the clarifier in winter to a level that will enable OCWA to shut down the North plant?

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Table 5.3

Objective: FINAL RUNS

Date: July 26, 1996 Sample Volume: 2 L Run #: 12

Chemical Dosages (mg/L)

Jar	PACL	LT24 (C)		Caustic	Alum	8170 (C)			
1	120	0.13							
2	120	0.13							
3				24	180	0.13			
4				24	180	0.13			
5									
6									

Observations

1	
2	
3	
4	
5	
6	

Chemical Analysis Data

	Supernatant				Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	0.20	5	–	–	0.13	4	–	–	–
2	–	–	–	–	–	–	–	–	–
3	0.85	14	–	–	0.46	8	–	–	–
4	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Combined supernatant from jars 1&2 and 3&4 to make up a 1.5 L sample for each treatment – each was then filtered.

Took Novamann Aquapak samples before chlorination.

Chlorinated to free res. of 0.5 mg/L after 10 min. & stored for 24 hrs. at 10 deg.C for SDS. Quenched THM samples were then collected. Samples #'s were MO–T–1 (alum+8170) and MO–T–2 (PACL+LT24).

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Table 5.4

Novamann Analytical Results for Final Runs

Parameter	Alum	PACL
Total THMs (ug/L)	16	30
Turbidity (NTU) *	1.4	0.8
Colour (TCU)	3	1
Total Organic Carbon	4.9	4.5
Free Chlorine Residual **	0.5	0.5
Total Alkalinity (as CaCO3)	22.0	25.0
Total Hardness (as CaCO3)	70.9	73.4
pH *	7.74	7.79
Conductivity (umho/cm)	337	300
Aluminum	0.162	0.074
Iron	0.103	0.023
Manganese	0.007	0.010
Copper	0.024	0.019
Lead	0.003	0.003
Zinc	0.029	0.017
Sodium	40.2	28.0
Potassium	2	2
Calcium	19.0	19.6
Magnesium	5.72	5.94
Sulphate	78.8	10.2
Chloride	42.7	77.1
Fluoride	0.3	0.4
Nitrate–N	<0.1	0.2
Nitrite–N	<0.1	<0.1
Ammonium–N	0.21	<0.05

All units are mg/L unless otherwise noted.

* Results for these parameters are unreliable unless measured at time of sampling.

** Measured in MOE lab 10 minutes after chlorine addition. There was a measureable residual after 24 hours SDS contact.

6.0 FULL SCALE TESTING

Full scale testing using polyaluminum chloride (PACL) and LT20 polymer was performed at the Moosonee South Water Treatment Plant to evaluate if PACL is better than alum at removing colour, turbidity and THMs precursors under real operating conditions. The full scale evaluation was performed at the Moosonee South plant from February 4 to 7, 1997.

6.1 ON-SITE TESTING

The following parameters were measured on-site:

- Aluminum residual: DR2000 (ECR method)
- Chlorine residual: DR2000
- Turbidity: Turbidity meter 2100 P
- Colour: DR2000

6.2 DAILY PROCESS MONITORING AND TESTING

Polyaluminum chloride was tested at the plant full scale on February 5, 6 and 7, 1997. The dosage tested was 68 mg/L combined with polymer LT20 at a dosage of 0.8 mg/L. Water samples were collected on February 4 to compare the performance of PACL versus the performance of alum. Alum was applied at a dosage of approximately 110 mg/L with the plant polymer LT20. The switch to PACl was initiated on the afternoon of February 4. Parameters such as turbidity, colour, pH, alkalinity, chlorine residual and aluminum were tested on-site by the MOE. The results are summarized in Table 6.1. Detailed results are presented in Appendix C.

PACl was tested with the plant flow rate at 700 L/min and 800 L/min to evaluate the maximum possible flow rate. It was found that PACL performed better at a flow rate of 700 L/min. Floc carry over to the filter was observed for a flow rate of 800 L/min.

Additional water sampling was performed on February 17, 18 and 19, 1997 when the plant was back to its normal operation and dosing alum. Maxxam Analytics analyzed the water samples for that period. Results are summarized in Table 6.1.

6.3 PLANT OBSERVATIONS

The results indicate a slight improvement in the turbidity level of the treated water with turbidity ranging from 0.1 to 0.30 NTU when dosing 68 mg/L of PACL and 0.8 mg/L of LT20. The turbidity of the raw water for the two days ranged from 2.72 to 3.20 NTU.

The true colour in the treated water on February 5 and 6 when dosing PACl was 7 TCU. The true colour results for the treated water sampled from February 17 to 19 when dosing alum indicate a colour level of 6 TCU. There was little difference in colour removal.

Maxxam Analytics analyzed all samples for aluminum residual except for samples on February 6 and 7 which was analyzed on-site by the MOE. The analytical method used by Maxxam Analytics is the ICP method (Inductively Coupled Plasma Atomic Emission Spectroscopy). Aluminum was tested on-site with a DR 2000 using the ECR method (Erichrome Cyanine Reagent). The Maxxam results for February 6 when dosing PACL show a level of aluminum residual in the treated water of 91 µg/L which is below the ODWO of 100 µg/L. The on-site measurement was 26 µg/L. The on-site aluminum residual results measured on February 7 with PACL was 19 µg/L. The different analytical method used may explain the lower levels measured on-site February 6 and 7. The aluminum residual level measured when dosing alum from February 17 to 19 varied from 94 to 116 µg/L. The limited amount of data available when dosing PACL makes it difficult to conclude if PACL effectively reduced the level of aluminum residual in the treated water.

TABLE 6.1 FEBRUARY 1997 WATER SAMPLING TO COMPARE ALUM AND PACL
MOOSONEE SOUTH WATER TREATMENT PLANT
WATER SAMPLES ANALYZED BY MAXXAM ANALYTICS AND MOE SD BRANCH

PARAMETERS	Alum + LT20	PACl + LT20			Alum + LT20 $^{(2)}$		
	(97/02/04)	(97/02/05)	(97/02/06)	(97/02/07)	(97/02/17)	(97/02/18)	(97/02/19)
Turbidity - Raw Water (NTU) $^{(1)}$	3.40	3.20	3.04	2.72	2.50	2.50	2.50
Turbidity - Treated Water (NTU)	0.30	0.30	0.15	0.10	0.67	0.60	0.68
Colour - Raw Water (TCU) $^{(a)}$ apparent	85 $^{(1)(a)}$	41	42	67$^{(1)(a)}$	37	36	36
Colour - Treated Water (TCU)	3 $^{(1)}$	7	7	1$^{(1)}$	6	6	6
pH - Raw Water	7.3	8.0	8.0	-	8.2	8.0	8.0
pH - Treated Water	7.0	7.7	7.7	-	7.2	7.3	7.3
Alkalinity - Raw Water (mg/L - $CaCO_3$)	264 $^{(1)}$	233	235	-	247	245	250
Alkalinity - Treated Water (mg/L - $CaCO_3$)	248 $^{(1)}$	205	200	-	155	172	172
Aluminum - Raw Water (ug/L)	-	150	145	-	113	95	79
Aluminum - Treated Water (ug/L)	-	142	91, 26 $^{(1)}$	19 $^{(1)}$	108	116	94
TOC - Raw Water (mg/L)	-	11.6	12.4	-	11.2	11.0	11.4
TOC - Treated Water (mg/L)	-	6.4	7.0	-	5.4	5.7	5.4
THMs - Unquenched Treated Water (ug/L)	-	53	79	97	82	75	75
Free Chlorine Residual (mg/L) $^{(1)}$	0.35	-	0.61	0.29	0.39	0.39	0.31
Total Chlorine Residual (mg/L)	-	-	0.98	-	-	-	-

NOTES: Analyzed by Maxxam Analytics
(unless indicated otherwise)
$^{(1)}$ Analyzed on-site

Removal of total organic carbon in the treated water appeared lower when dosing alum with levels ranging from 5.4 to 5.7 mg/L. The TOC concentration measured when dosing PACL was 6.4 to 7 mg/L. Again, the number of data collected is too limited to evaluate the real impact of dosing PACL on TOC removal.

The level of THMs measured in the treated water at the plant when dosing PACL varied from 53 to 97 μg/L, and the level of THMs when dosing alum varied from 75 to 82 μg/L. The results indicate that both coagulants are comparable in terms of THMs formation. The level of THMs remained under 100 μg/L for both coagulants which is normally expected for that time of the year.

The results of the full scale plant testing indicate that there is no real benefits regarding colour, aluminum residual and THMs formation to switch to PACL. Therefore, it is recommended to continue using alum as primary coagulant.

7.0 CONCLUSIONS

Generally, the plant staff is keeping up with the process and is producing good water. Specifically there has been a tremendous improvement over the past two years due to the efforts of the Ontario Clean Water Agency (OCWA) operating staff.

The improvement of plant performance regarding turbidity, colour, aluminum residual and THMs precursor removal when using PACL is marginal, compared to alum, and would not justify the increase in operating costs. Therefore, it is recommended to continue using alum.

Information collected from the water plant shows that the free chlorine residual is normally maintained between 0.3 and 0.5 mg/L. Maintaining a free chlorine residual of 0.5 mg/L under cold water temperature, and 0.3 mg/L for the summer condition is sufficient to provide adequate inactivation of giardia cysts, providing that a minimum free chlorine residual of 0.2 to 0.3 mg/L can be maintained at the end of the distribution system. The post caustic feed location must remain at the clearwell outlets to allow the above free chlorine residual to be used.

In general the Moosonee South Water Treatment Plant met the health related Ontario Drinking Water Objectives. However, the plant performance was somewhat variable. This is due primarily to the highly variable raw water quality in the Store Creek supply and the process limitations of the existing plant.

The plant significantly exceeds the interim guideline for aluminum residual which can cause degradation of water quality in the reservoirs and watermains. Further process modifications are required to deal with the aluminum problem including independent pH/alkalinity adjustment of the raw water. The results of the water sampling performed in 1997 showed that the average THMs levels have been reduced to below the guideline level. A lower pH will reduce the formation of

THMs, but increase the corrosiveness of the plant effluent and could lead to degradation of water quality in the distribution system. A balance between the optimum pH to reduce THMs and the pH required to minimize corrosion would be approximately 7.5.

At times of high demand the plant staff must run the old Base Water Treatment Plant. While sampling and optimization at this plant was not part of the optimization study, it is our experience that this plant is not capable of achieving the same effluent quality as the South plant. This facility is in poor condition and well beyond its useful life. Water from the Base plant blends with water from the South plant in the Base reservoir and will potentially degrade the overall quality.

8.0 RECOMMENDATIONS

The following is a summary of recommendations for plant and operational modifications required to ensure that the Moosonee South Water Treatment Plant will comply with the ODWO for THMs and aluminum residual, and will be more capable of achieving a turbidity in the filter effluent of 0.1 NTU:

1. An acid feed system should be installed to provide independent and automatic control over raw water pH. Either sulfuric acid or carbon dioxide can be used for pH adjustment. Addition of an acid feed system would allow using straight alum all year around. This would improve the overall coagulation/flocculation process. There is an existing pH meter installed on the Reactivator inlet water line, but the system should include a permanent pH monitoring set-up with a smaller sample basin to reduce the lag time in obtaining results.

2. A back-up pH monitoring system at least in storage would be meaningful given the important nature of this instrument.

3. Installation of a new automatic pH controller for the raw water to help maintain the optimum pH of the raw water prior to alum injection. The optimum pH would be controlled by addition of either acid or caustic, depending on the raw water condition. The operation of the acid and caustic soda feeding pumps would be controlled by the on-line pH meter. Injection of alum would be paced on the raw water flowmeter.

4. Installation of a new pH monitoring and control system for the treated water to help maintain a pH of 7.5 to 8.0 in the treated water, since it is expected that a pH level between 7.0 and 7.5 may cause corrosion problems in the distribution system.

5. If required after items 1 to 4 are completed perform chloramination of the treated water leaving the plant by adding ammonium sulphate at the high lift pump header to stop any further THMs formation in the distribution system. This would insure that THMs levels in the treated water will not exceed 100 µg/L particularly during warm water conditions.

6. The coagulant and disinfection feed systems should have fully functional back-ups to allow quick change-over in the event of a problem.

7. Increase the turn over of the reservoirs located in town to eliminate long contact times and reduce the possibility for THMs formation. This recommendation would not be required if the plant converts to chloramination.

8. This plant is near or sometimes over its hydraulic capacity and a plant expansion will be required in the near future.

9. Re-locate post caustic feed to clearwell outlet.

10. The recommended modifications in 1-9 should be considered for incorporation into any new treatment facility, depending on the raw water source chosen.

9.0 COST ESTIMATE FOR IMPLEMENTATION

Table 9.1 is a summary of capital expenditure involved for the implementation of the recommended upgrades. The figures presented are preliminary estimates prepared to give an idea of the price range involved.

TABLE 9.1 Capital Cost Estimates

PROPOSED MODIFICATIONS	COST ($)
Acid feed system including piping and accessories.	$8,000
One back-up pH monitoring system for the raw water pH adjustment.	$2,000
One automatic controller for the raw water pH.	$6,000
One new on-line pH monitoring system for the treated water.	$2,000
Ammonium sulphate feed system to perform chloramination of the treated water including two dosing pumps, one day tank and mixer, piping and accessories, and one chlorine analyser.	$10,000
One back-up dosing pump for the alum dosing system, and one back-up dosing pump for the chlorine dosing system.	$8,000
TOTAL:	**$36,000**

GLOSSARY AND LIST OF ABBREVIATIONS

Alum : aluminum sulphate

CT : Value required to achieve adequate inactivation and/or removal of cysts and viruses. T is the time (in minutes) it takes the water during peak hourly flow, to move between the point of disinfectant and a point where C, the residual disinfectant concentration (mg/L), is measured prior to the first customer.

d : day

°C : degree Celsius

DWSP : Drinking Water Surveillance Program

ECR reagent : Eriochrome Cyanine R

FID : Flame Ionization Detector

ft : foot

G : flocculation energy gradient

Gt : flocculation energy

GC/MS : Gas Chromatograph / Mass Spectrometry

GAC : Granular Activated Carbon

g : gram

h : hour

HFS : hydroxylated ferric sulphate (Ferriclear)

ICP : Inductively Coupled Plasma Atomic Emission Spectoscopy

IG : imperial gallon

kW : kilowatt

L : litre

L/cap.d : litres per capita per day

L/s : litres per second

m : metre

m^2 : square metres

m^3 : cubic metres

m^3/d	: cubic metres per day
m/h	: metres per hour (equivalent m^3/m^2.h - filtration rate)
µg/L	: micrograms per litre
mg/L	: milligrams per litre
mm	: millimetre
mL/min	: millilitres per minute
min	: minute
NTU	: Nephelometric Turbidity Unit
OCWA	: Ontario Clean Water Agency
ODWO	: Ontario Drinking Water Objective
%	: percent
PACL	: polyaluminum chloride
PVC	: polyvinyl chloride
lb	: pound
rpm	: revolution per minute
SOR	: Surface Overflow Rate
SWTR	: Surface Water Treatment Rule
T_{10}/T	: This factor describes the baffling condition in the clearwell, and represents the ratio between T_{10}, which is the time it takes 10 percent of a dye or tracer to be detected at the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mixed chamber.
TOC	: Total Organic Carbon
THMs	: Trihalomethanes
TCU	: True Colour Unit
W/V	: weight/volume

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APPENDICES

Plant Survey

Appendix A

PLANT **Moosonee South**
Shipping Address: Box 459, 1 Resource Road, Moosonee, Ontario P0L 1Y0

Tel: (705) 336-2504 Fax: (705) 336-2953

PREPARED BY: **R.A. LeCraw, P.Eng.**
DATE: Plant Visit May 22, 23, 1996

STAFF:
Superintendent: John McGhee
No. of Operators: 3
Names of Operators:
Steve Prewieda, Aaron Morrision

Hours in Attendance: 8h/d (2 water plants, 2 sewage plants) Certified Y/N: Y

PLANT CAPACITY:

Average Daily Flow:	935 m^3/d (650 L/min)
Maximum Daily Flow:	1,080 m^3/d (750 + L/min)
Rated Plant Capacity:	1,080 m^3/d (750 L/min)
Population Served:	2,000

OPERATING AUTHORITY:
Ontario Clean Water Agency

YEAR OF CONSTRUCTION: Original 1964 +/-
Up-Grade 1984

SOURCE OF RAW WATER: Store Creek

RAW WATER CHARACTERISTICS:

• Colour:	40 - 300 TCU
• Turbidity:	2 – 30 NTU
• pH:	7.1 – 8.0
• Alkalinity:	40 – 312 mg/L

CHEMICALS:

- Coagulant: Type: Alum, Acidified Alum (A-10, A-15, A-20)
  Dosage: 170 mg/L (Summer), 110 mg/L (Winter)
  Injection Point: In-line static mixer raw water line.

- Coagulant Aid: Type: LT 20, 24
  Dosage: 0.5 – 1 mg/L
  Injection Point: Directly into mixing well of Reactivator.

- Alkalinity/pH Adjustment: Chemical Used: Caustic Soda
  Dosage: 10 –40 mg/L
  Injection Point: Pre at static mixer, and post after filters.

- Disinfection: Type: Sodium Hypochlorite
  Dosage: 2 – 4 mg/L
  Injection Point: Post only, after filters.

ANALYSIS DONE AT THE LAB:
Colour
Alkalinity
Turbidity
pH

LAB EQUIPMENT AVAILABLE:
- Hach DR 2000
- pH meter
- 2100 P Turbidimeter

PROCESS CONFIGURATION:

CHEMICALS METERING:

	TYPE	CAPACITY	CONTROL	CONDITION
Coagulant:	Acidified Alum, Alum (W&T 748 metering pump)		Manual control only	Fair No stand-by
Coagulant Aid:	LT 20 (W&T 748 metering pump)		Manual control only	Fair. No Standby
• Alkalinity /pH Adjustment:	Caustic Soda (W&T 748 metering pump)		Manual control only	Fair. No Standby
• Disinfection:	Sodium Alum Hypochlorite (W&T 748 metering pump)		Manual control only	Fair. No Standby
• Other:				

PROCESS CONFIGURATION (Continued):

INTAKE:	TYPE				CONDITION	NOTES
SCREENING:	TYPE	NO	DIMENSIONS		CONDITION	NOTES
LOW LIFT PUMPS:	TYPE	NO		CAPACITY	CONDITION	NOTES
	Flyght Submersible	2		750 L/min + EACH 7.3 kW (9.8 hp)		
HIGH LIFT PUMPS:	TYPE	NO		CAPACITY	CONDITION	NOTES
	Layne Vertical Turbine	3		500 L/min EACH		
MIXING:	TYPE				CONDITION	NOTES
	In-line Mixer					
CLARIFICATION:	TYPE	NO	DIMENSIONS		CONDITION	NOTES
	Gravier Reactor/ Clarifier	2	React #1: 4.3m DIAM X 3.6m Depth, Floc: 1.9m DIAM React #2: 4.6m DIAM X 3.8m Depth, Floc: 1.9m DIAM			
CONTACT TANK:	TYPE	NO	DIMENSIONS	VOLUME	CONDITION	NOTES
		4	0.67m X 0.67m X 3.4m	1.5 m^3 EACH		
FILTERS:	TYPE	NO	DIMENSIONS	CAPACITY	CONDITION	NOTES
	Dual Media	4	1.83m DIAM			
CLEARWELL/: ON-SITE RESERVOIR		NO	DIMENSIONS	VOLUME	BAFFLED: Y/N	NOTES
	- 1 CELL CLEARWELL :		8.5 X 11.1 X 2.4m deep	226 m^3 TOTAL (50,000 IG)	YES	
	- 2 RESERVOIRS:			1, 136 m^3 TOTAL (250,000 IG)		CONCRETE, ABOVE GROUND

PLANT CONTROL:

• Flow (Manual Set/Auto):	Manually set by low lift pump selection and manual throttling of raw water flow.
• Level:	Level control on low lift pumps from clearwell.
• On/Off:	Plant on/off control from clearwell level.

PROCESS MONITORING:

	INSTRUMENT	MONITORING FREQUENCY	LOCATION	NOTES
• Turbidity:	Lab monitoring	Daily	Raw and treated	
• pH:	Continuous pH monitoring after alum and caustic are added. Alarmed.			
• Free Chlorine Residual:	Lab monitoring	Daily	Raw and treated	
• Total Chlorine Residual:				
• Temperature:	Periodically			
• Aluminum Residual:	MOE testing only.			
• Colour:	Lab monitoring	Daily	Raw and treated	
• Other:				

ISSUES:

Highly variable raw water quality. High colour (200 TCU+) corresponds to period of lowest alkalinity. Must pre-feed caustic for alkalinity addition. Lowest colour (80 TCU) in winter with high alkalinity. Currently using acidified alum to depress pH. Often has to use acidified alum and caustic soda.

Coagulant dosage requirements and pH control requirements vary in opposite direction therefore, it is very difficult to achieve optimum acidity level for alum. Addition of acidified alum and caustic soda at the same time is expensive and counter productive.

pH monitoring is good but could be more permanent installation. On-line turbidity monitoring of each filter effluent is required.

Independent pH/Alkalinity control would provide more direct control of pH.

CHECK LIST:

_ Copy of Certificate of Approval.

_ Copy of DWSP report if available. NA

_ Copy of monthly flows for the previous year. OK

_ Copy of the monthly analysis for the previous year to evaluate plant performance for the raw water, settled water and plant effluent. OK

Analysis of interest are: DOC, true colour, turbidity, pH, alkalinity, aluminum residual, chlorine residual, temperature and THMs.

Off-Site Treatability Testing

Appendix B

Table B1

Objective: Can we get away with a low enough alum dose to avoid caustic?

Date: July 22, 1996 Sample Volume: 1.5 L Run #: 1

Chemical Dosages (mg/L)

Jar	Alum	mL	LT20	mL					
1	80	12	0.1	0.15					
2	100	15	0.1	0.15					
3	120	18	0.1	0.15					
4	140	21	0.1	0.15					
5									
6									

Observations

1	No floc – ABANDON
2	Very fine pinfloc – ABANDON
3	Good quantity of small, fluffy floc; much has settled after 5 minutes; but still some in suspension
4	Good quantity of fluffy floc, a bit larger than #3; settles a bit faster than #3
5	
6	

Chemical Analysis Data

Supernatant					Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–
3	2.0	28	–	–	0.80	14	7.04	21	0.205
4	1.9	25	–	–	0.58	10	6.78	13	0.144
5									
6									
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Raw pH today was 7.29

Optimum alum dose was not reached and raw alkalinity has almost been used up

Next run should use caustic, alum, and LT20

As an aside, caustic was added to raw water at several doses – 1 mg/L caustic raises alkalinity by 1.1 mg/L

Table B2

Objective: Determine optimum alum dosage.

Date: July 23, 1996 Sample Volume: 1.5 L Run #: 2

Chemical Dosages (mg/L)

Jar	Caustic	mL	Alum	mL	LT20	mL			
1	17	2.6	160	24	0.1	0.15			
2	22	3.3	170	25.5	0.1	0.15			
3	26	3.9	180	27	0.1	0.15			
4	30	4.5	190	28.5	0.1	0.15			
5	34	5.1	200	30	0.1	0.15			
6	38	5.7	210	31.5	0.1	0.15			

Observations

1	All jars have a good quantity of small, fluffy floc; jars 3–6 are better than 1 & 2.
2	There is not a big difference in settling – there is still a fair bit left to settle after 5 minutes. Jars 5 & 6 are best, followed by 4, and 1,2,3 are worse.
3	
4	
5	
6	

Chemical Analysis Data

Supernatant					Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	1.15	18	–	–	0.30	8	7.69	26	0.077
2	0.70	12	–	–	0.22	7	7.59	25	0.067
3	0.69	14	–	–	0.21	7	7.43	25	0.060
4	0.69	13	–	–	0.35	8	7.37	25	0.114
5	0.63	11	–	–	0.31	5	7.31	25	0.098
6	0.60	12	–	–	0.37	8	7.31	27	0.131
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Optimum alum dosage appears to be 180 mg/L.

MOE /SCB Treatability Data Report – Moosonee South WTP

Table B3

Objective: Determine optimum alum dosage using sodium bicarb – is it better than caustic?

Date: July 23, 1996 Sample Volume: 1.5 L Run #: 3

Chemical Dosages (mg/L)

Jar	Bicarb	mL	Alum	mL	LT20	mL			
1	20	3	140	21	0.1	0.15			
2	30	4.5	150	22.5	0.1	0.15			
3	38	5.7	160	24	0.1	0.15			
4	48	7.2	170	25.5	0.1	0.15			
5	56	8.4	180	27	0.1	0.15			
6	65	9.8	190	28.5	0.1	0.15			

Observations

1	Floc very small and settles poorly – ABANDON
2	FLOC QUALITY: small fluffy floc – #2 is small, #3–5 are bigger still, #6 a bit bigger than the rest.
	SETTLING: #6 is best, #3 and 5 are close behind, followed by #4, then #2, then #1. After 5 minutes
3	#6 and 5 are well – settled; settling seems better than in Run #2.
4	
5	
6	

Chemical Analysis Data

	Supernatant				Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	–	–	–	–	–	–	–	–	–
2	2.1	25	–	–	1.2	17	5.90	25	>0.220
3	2.4	27	–	–	1.3	15	6.00	26	>0.220
4	2.4	26	–	–	1.2	14	6.06	28	>0.220
5	2.5	28	–	–	1.3	16	6.09	27	–
6	2.8	30	–	–	1.5	17	6.13	26	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Results were unexpected – treatment is terrible when bicarb is used.

I will try bicarb again later in study to see if this happens again.

Table B4

Objective: Determine optimum PACL dosage.

Date: July 24, 1996 Sample Volume: 1.5 L Run #: 4

Chemical Dosages (mg/L)

Jar	PACL	mL							
1	110	16.5							
2	120	18							
3	130	19.5							
4	140	21							
5	150	22.5							
6	160	24							

Observations

1	FLOC QUALITY: Floc is poor in all jars (that was expected–no polymers), there appears to be a little more of it in jars #5 & 6.
2	SETTLING: Jars #5 & 6 are a little better than others.
3	
4	
5	
6	

Chemical Analysis Data

Supernatant					Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	0.44	11	–	–	0.14	5	6.07	32	0.035
2	0.29	8	–	–	0.12	5	6.12	29	0.033
3	0.29	7	–	–	0.14	4	6.12	–	0.040
4	0.32	7	–	–	0.20	4	6.15	22	0.049
5	0.30	5	–	–	0.21	5	6.13	–	0.058
6	0.35	6	–	–	0.20	3	6.14	16	0.100
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Based on water quality (floc irrelevant without polymer), 120 mg/L was selected as optimum.

It looks like pre–alkalinity adjustment will not be needed with PACL (1 mg/L drops alkalinity by 0.3 mg/L).

MOE /SCB Treatability Data Report – Moosonee South WTP

Table B5

Objective: Determine optimum Ferriclear dosage.

Date: July 24, 1996 Sample Volume: 1.5 L Run #: 5

Chemical Dosages (mg/L)

Jar	Caustic	mL	Ferriclear	mL					
1	29	4.4	150	22.5					
2	34	5.1	160	24					
3	38	5.7	170	25.5					
4	43	6.5	180	27					
5	47	7.1	190	28.5					
6	52	7.8	200	30					

Observations

1	FLOC QUALITY: Large quantity of small floc in all jars.
2	SETTLING: All jars are similar – there is a fair bit of settling left to go after 5 minutes – still not fully settled after 20 minutes.
3	
4	
5	
6	

Chemical Analysis Data

Supernatant					Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	2.1	44	–	–	0.82	17	6.21	–	–
2	1.2	28	–	–	0.69	14	6.18	–	–
3	1.3	30	–	–	0.58	13	6.13	–	–
4	1.7	34	–	–	0.51	12	6.03	10	–
5	1.4	28	–	–	0.28	6	6.08	9	–
6	1.3	30	–	–	0.49	11	6.06	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Difficult to select optimum – run again with LT20 polymer.

Table B6

Objective: Determine optimum Ferriclear dosage.

Date: July 24, 1996 Sample Volume: 1.5 L Run #: 6

Chemical Dosages (mg/L)

Jar	Caustic	mL	Ferriclear	mL	LT20	mL			
1	39	5.9	160	24	0.13	0.2			
2	43	6.5	170	25.5	0.13	0.2			
3	48	7.2	180	27	0.13	0.2			
4	52	7.8	190	28.5	0.13	0.2			
5	57	8.6	200	30	0.13	0.2			
6	61	7.8	210	31.5	0.13	0.2			

Observations

1	FLOC QUALITY: Large quantity of floc in all jars. There is a gradation in size from 1 (fine) to 6 (large fluffy).
2	SETTLING: Overall improvement with LT20 – gradation from 1 (worst) to 6 (best). After 5 minutes,
	the best is 5, then 4&6, then 3, then 2, then 1.
3	
4	
5	
6	

Chemical Analysis Data

	Supernatant				Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	1.1	29	–	–	0.36	6	–	17	–
2	0.58	11	–	–	0.22	7	–	–	–
3	0.50	11	–	–	0.26	5	–	–	–
4	0.36	8	–	–	0.20	4	–	–	–
5	0.33	4	–	–	0.22	4	–	13	–
6	0.33	10	–	–	0.21	4	–	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Optimum dosage appears to be 200 mg/L.

MOE /SCB Treatability Data Report – Moosonee South WTP

Table B7

Objective: Find the best polymer to use with PACL.

Date: July 25, 1996 Sample Volume: 1.5 L Run #: 7

Chemical Dosages (mg/L)

Jar	PACL	mL	LT20 (N)	LT22 (C)	LT24 (C)	8170 (C)	A110 (A)	6466 (A)	
1	120	18	0.13						
2	120	18		0.13					
3	120	18			0.13				
4	120	18				0.13			
5	120	18					0.13		
6	120	18						0.13	

Observations

1	Small fluffy floc initially; improves a little after 10 minutes slow mix.
2	Larger than #1; improves after 10 minutes slow mix.
3	Fluffy floc larger than #2; settling nearly complete after 5 minutes.
4	Floc same as #3; settling a bit slower than #3.
5	Small floc similar to #1.
6	Very poor floc – ABANDON.
	FLOC QUALITY: #3 & 4 best, then #1 & 2, then #5, then #6.
	SETTLING: #3 best, then #4, then #1, then #2, then #5, then #6.

Chemical Analysis Data

	Supernatant				Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	0.19	6	–	–	0.19	3	–	–	0.026
2	0.19	7	–	–	0.12	5	–	–	0.029
3	0.12	5	–	–	0.13	4	–	–	0.027
4	0.13	4	–	–	0.11	4	–	27	0.026
5	0.23	4	–	–	0.13	4	5.99	–	0.029
6	–	–	–	–	–	–	–	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Supmatant and filtrate is superb with all polymers, better than PACL alone.

Based on floc, Percol LT24 is best polymer (8170 is good too).

Table B8

Objective: Find the best polymer to use with alum.

Date: July 25, 1996 **Sample Volume:** 1.5 L **Run #:** 8

Chemical Dosages (mg/L)

Jar	Caustic	Alum		LT20 (N)	LT22 (C)	LT24 (C)	8170 (C)	LT31 (C)	LT35 (C)
1	24	180		0.13					
2	24	180			0.13				
3	24	180				0.13			
4	24	180					0.13		
5	24	180						0.13	
6	24	180							0.13

Observations

1	Very small floc.
2	Small floc, but larger than #1.
3	Floc larger than #2.
4	Floc larger than #3; after 5 min. settling there is still a fair bit in suspension.
5	No floc – ABANDON.
6	No floc – ABANDON.
	FLOC QUALITY: #4 best, followed by #3, then #2, then #1, then #5,6.
	SETTLING: #4 best, followed by #3, then #1&2, then #5&6.
	With same polymers, the PACL jars in previous run settled faster.

Chemical Analysis Data

Supernatant					Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	0.90	15	–	–	0.41	10	–	25	0.120
2	0.83	13	–	–	0.35	8	6.11	–	0.088
3	0.69	11	–	–	0.21	6	6.12	–	0.070
4	0.69	12	–	–	0.27	5	–	23.5	0.078
5	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Suprnatant and filtrate not as good as PACL run.

Based on floc and water quality, 8170 is the best polymer (LT24 is good too).

In this run I replaced A110 and 6466 (they are both duds here and in Fauquier tests) with LT31 and LT35.

Table B9

Objective: Find the best polymer to use with Ferriclear.

Date: July 25, 1996 Sample Volume: 1.5 L Run #: 9

Chemical Dosages (mg/L)

Jar	Caustic	Ferriclear		LT20 (N)	LT22 (C)	LT24 (C)	8170 (C)	233N (N)	LT31 (C)
1	64	200		0.13					
2	64	200			0.13				
3	64	200				0.13			
4	64	200					0.13		
5	64	200						0.13	
6	64	200							0.13

Observations

1	FLOC QUALITY: Floc in all jars is poor quality, especially #1, 2 & 6.
2	
3	SETTLING: #5 best, followed by #4, then #3, then #1&2, then #6.
4	
5	
6	

Chemical Analysis Data

Supernatant					Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	0.90	19	–	–	–	–	–	–	–
2	0.92	20	–	22	–	–	–	–	–
3	0.87	14	–	–	–	–	–	–	–
4	0.73	15	–	–	–	–	–	–	–
5	0.53	11	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

I did not bother to do filtrate since Ferriclear seems to be a lost cause – high dosage and poor floc quality.

Based on floc and water quality, 233N is the best polymer.

It's interesting to note than with alum, PACL and Ferriclear, the LT24 and 8170 do fairly well.

I will try 233N in next run with alum and PACL.

Table B10

Objective: Try out other polymers to use with PACL and alum.

Date: July 25, 1996 Sample Volume: 1.5 L Run #: 10

Chemical Dosages (mg/L)

Jar	PACL	LT24 (C)	233N (N)	LT31 (C)	Caustic	Alum	8170 (C)	233N (N)	579C (C)
1	120	0.13	–	–					
2	120	–	0.13	–					
3	120	–	–	0.13					
4					24	180	0.13	–	–
5					24	180	–	0.13	–
6					24	180	–	–	0.13

Observations

1	Fair–sized fluffy floc.
2	Floc smaller than #1.
3	Floc smaller than #2.
4	Good floc, better than #1.
5	Good quantity of small floc.
6	Pinfloc – ABANDON.
	SETTLING: No surprise – #1 & 4 best, then #2 & 5, then #3, then #6.
	The difference in sludge thickness in the bottom of the jars is striking – the PACL
	jars have 2X the amount (comparing jars #1 and 4).

Chemical Analysis Data

	Supernatant				Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

No chemistry was done because the intent was to identify a good poly (ie. a good floc producer) that I did not yet try.

The LT24 (alum) and 8170 (PACL) were the best in this run by far.

Table B11

Objective: Try out other polymers with PACL / Compare caustic vs. bicarb. for alum+8170 treatment.

Date: July 25, 1996 Sample Volume: 1.5 L Run #: 11

Chemical Dosages (mg/L)

Jar	PACL	LT25 (C)	LT26 (C)			Caustic	Bicarb	Alum	8170 (C)
1	120	0.13	–						
2	120	–	0.13						
3						24	–	180	0.13
4						–	56	180	0.13
5									
6									

Observations

1	Very poor floc.
2	Very poor floc.
3	Good size fluffy floc.
4	Same size as #3, but more compact and strong, and settles faster. After 5 minutes nearly complete settling.
5	
6	

Chemical Analysis Data

Supernatant					Filtrate				
Jar	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Al. Res.
1	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–
3	0.81	13	–	–	0.55	8	–	–	0.143
4	2.3	23	–	–	1.1	10	–	27	0.203
5	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

The same holds true with 8170 as with LT20 in run #2; supernatant and filtrate quality is very poor with bicarb.

It is interesting to note that with bicarb the floc properties are better, both in this run and in run #2.

Full Scale Plant Testing

Appendix C

FIELD DATA SHEET – MOOSONEE

Date	Time	Raw Turb.	Clar. Eff. Turb.	Filt. Eff. Turb.	Treated Turb.	Raw Colour	Clar. Eff. Colour	Filt. Eff Colour	Treated Colour	Raw Alky.	Treated Alky.	Raw pH	Treated pH	Free Cl2	Total Cl2	Resid Al
04/02	15:00	3.4	–	1 – 0.2	0.3	65			3			7.3	7.0			
				2 – 0.3												
				3 – 0.2												
				4 – 0.3												
05/02	14:35	3.2	0.8		0.3							7.6	7.2			
06/02	8:30	2.80	1 – 0.54	1 – 0.28	0.15	78	1 – 4		1	270	244	7.6	7.4	0.81	0.88	0.051
			2 – 0.45	2 – 0.38			2 – 1									
				3 – 0.30												
				4 – 0.24												
06/02	11:30	2.81	1 – 0.98	1 – 0.16	0.18	86	1 – 11	1 – 5	2							
			2 – 0.65	2 – 0.10			2 – 5	2 – 0								
				3 – 0.17				3 – 1								
				4 – 0.20				4 – 1								
06/02	13:30	3.28	1 – 0.76	1 – 0.27	0.11	101	1 – 12	1 – 3	3							
			2 – 0.83	2 – 0.11			2 – 14	2 – 4								
				3 – 0.11				3 – 4								
				4 – 0.14				4 – 2								
06/02	14:30		1 – 0.71				1 – 6									
			2 – 0.68				2 – 8									
06/02	15:00		1 – 0.72				1 – 10									
			2 – 1.23				2 – 15									
06/02	15:30	3.04	1 – 0.76	1 – 0.25	0.17	73	1 – 8	1 – 0	1					0.28		0.026
			2 –	2 – 0.28			2 –	2 – 3								
				3 –				3 –								
				4 –				4 –								
07/02	8:00	2.62	1 – 0.78	1 – 0.21	0.15	62	1 – 15	1 – 7	0					0.30		0.018
			2 – 0.60	2 – 0.15			2 – 8	2 – 5								
				3 – 0.13				3 – 5								
				4 – 0.08				4 – 2								
07/02	10.30	2.70	1 – 0.76	1 – 0.13	0.08	71	1 – 0	1 – 2	3							
			2 – 0.51	2 – 0.12			2 – 7	2 – 2								
				3 – 0.13				3 – 3								
				4 – 0.14				4 – 1								
07/02	13.30	2.81	1 – 0.75	1 – 0.18	0.08	68	1 – 13	1 – 4	0					0.27		
			2 – 0.52	2 – 0.12			2 – 7	2 – 0								
				3 – 0.10				3 – 0								
				4 – 0.09				4 – 0								

OPERATING DATA SHEET – MOOSONEE

Date	Time	Coag. Type	Coag. Dose	Polymer Type	Polymer Dose	Cl2 Dose	" " Dose	" " Dose	Plant Flow Rate (L/mln)	COMMENTS
05/02	15:00	PACl	60	LT20	0.8				700	
06/02	9:00	PACl	68	LT20	0.8				700	– all filters were backwashed thls mornlng
06/02	11:30	PACl	68	LT20	0.8				700	
06/02	11:45	PACl	68	LT20	0.8				800	–plant flow rate boosted to 800 L/min
06/02	15:30	PACl	68	LT20	0.8				800	– clarifier #2 lost part of blanket
										– rose throughout afternoon
06/02	15:45	PACl	68	LT20	0.8				700	– rate lowered
07/02	8:00	PACl	68	LT20	0.8				700	– blanket much better at 700

Analytical Procedures used by Novamann

Appendix D

Detection Limit and Analytical Method Reference used by Novamann

PARAMETERS	MINIMUM DETECTION LIMIT(MDL)	ANALYTICAL METHOD	METHOD REFERENCE*
THM	6 µg/L	Purge &Trap GC/MS	EPA 624
TOC	0.1 mg/L	UV/PEROX/FID	EPA 9060
residual aluminum	0.025 mg/L	ICP	EPA 6010
turbidity	0.1 NTU	Turbidity Meter	APHA 2130
true colour	1 TCU	Colourimetric	APHA 2120
pH	0.01	pH Meter	APHA 4500H
alkalinity	1 mg/L - $CaCO_3$	Titration	APHA 2320
ammonia + ammonium	0.05 mg/L	Colourimetric	APHA 4500
anions (NO_3, Cl, SO_4, F)	0.1 to 0.5 mg/L	Ion Chromatography	EPA 300.0
conductivity	1 umho	Conductivity Meter	APHA 2510
lead	0.002 mg/L	Graphite Furnace	EPA 7421
metals		ICP	EPA 6010
nitrite	0.1 mg/L	Colourimetric	APHA 4500
orthophosphate-P	0.005 mg/L	Colourimetric	APHA 4500

Note * : EPA : Environmental Protection Agency
APHA : American Public Health Association

Evaluation of Residual Chlorine Concentration for Inactivation of Giardia Cysts

Appendix E

MOOSONEE SOUTH WATER TREATMENT PLANT

E.1 Evaluation of residual chlorine concentration required for 3-log inactivation of giardia cysts for a raw water temperature of 0.5 °C and the clearwell 50% full:

NOTES:

- The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts.
- Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 0.5-log inactivation =	33	(at 0.5 °C or lower, pH=7.0 and Conc. = 0.5 mg/L)
	23	(at 5 °C, pH=7.0 and Conc. <= 0.4 mg/L)
	17	(at 10 °C, pH=7.0 and Conc. <= 0.4 mg/L)
	12	(at 15 °C, pH=7.0 and Conc. <= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell	226 m^3
% Full =	0.5
T_{10}/T =	0.5
Max. Day Flow =	1,080 m^3/d
Raw water temp.:	0.5 °C

T = **75 Minutes**

Evaluation of Residual Chlorine Concentration (C):

C = CT for 0.5-log inactivation / T
CT = 33

$\boxed{C = \mathbf{0.44\ mg/L}}$

MOOSONEE SOUTH WATER TREATMENT PLANT

E.2 Evaluation of residual chlorine concentration required for 3-log inactivation of giardia cysts for a raw water temperature of 5 °C and the clearwell 50% full:

NOTES:

- The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts.
- Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 0.5-log inactivation =	33	(at 0.5 °C or lower, pH=7.0 and Conc. = 0.5 mg/L)
	23	(at 5 °C, pH=7.0 and Conc. <= 0.4 mg/L)
	17	(at 10 °C, pH=7.0 and Conc. <= 0.4 mg/L)
	12	(at 15 °C, pH=7.0 and Conc. <= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell	226 m^3
% Full =	0.5
T_{10}/T =	0.5
Max. Day Flow =	1,080 m^3/d
Raw water temp.:	5 °C

T = **75 Minutes**

Evaluation of Residual Chlorine Concentration (C):

C = CT for 0.5-log inactivation / T
CT = 23

$\boxed{C = 0.31 \text{ mg/L}}$

MOOSONEE SOUTH WATER TREATMENT PLANT

E.3 Evaluation of residual chlorine concentration required for 3-log inactivation of giardia cysts for a raw water temperature of 10 °C and the clearwell 50% full:

NOTES:

* The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts.
* Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 0.5-log inactivation =	33	(at 0.5 °C or lower, pH=7.0 and Conc. = 0.5 mg/L)
	23	(at 5 °C, pH=7.0 and Conc. <= 0.4 mg/L)
	17	(at 10 °C, pH=7.0 and Conc. <= 0.4 mg/L)
	12	(at 15 °C, pH=7.0 and Conc. <= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell	226 m^3
% Full =	0.5
T_{10}/T =	0.5
Max. Day Flow =	1,080 m^3/d
Raw water temp.:	10 °C
T =	**75 Minutes**

Evaluation of Residual Chlorine Concentration (C):

C = CT for 0.5-log inactivation / T
CT = 17

C = 0.23 mg/L

MOOSONEE SOUTH WATER TREATMENT PLANT

E.4 Evaluation of residual chlorine concentration required for 3-log inactivation of giardia cysts for a raw water temperature of 15 °C and the clearwell 50% full:

NOTES:

* The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of giardia cysts.
* Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts.

CT for 0.5-log inactivation =

33 (at 0.5 °C or lower, pH=7.0 and Conc. = 0.5 mg/L)
23 (at 5 °C, pH=7.0 and Conc. <= 0.4 mg/L)
17 (at 10 °C, pH=7.0 and Conc. <= 0.4 mg/L)
12 (at 15 °C, pH=7.0 and Conc. <= 0.4 mg/L)

Where C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

T= [Volume of Clearwell (m^3) x %Full x Baffling Condition (T_{10}/T)] / [Maximum Day Flow (m^3/d)] x 1,440 min/d

Volume of Clearwell 226 m^3
% Full = 0.5
T_{10}/T = 0.5
Max. Day Flow = 1,080 m^3/d
Raw water temp.: 15 °C

T = 75 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 0.5-log inactivation / T
CT = 12

$\boxed{C = 0.16 \text{ mg/L}}$